

MANUAL AND AUTOMATIC VOLUME CONTROLS

19FR-2

NATIONAL RADIO INSTITUTE

ESTABLISHED 1914

WASHINGTON, D. C.



STUDY SCHEDULE No. 19

For each study step, read the assigned pages first at your usual speed. Reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind, then answer the Lesson Questions for that step. Study each other step in this same way.

☐ 1. Why Volume Controls Are Needed Pages 1-6

The purpose of a volume control in a receiver, and the difference between automatic and manual volume controls, is explained here. Then, there is a discussion of R.F. and A.F. voltage control systems. Answer Lesson Questions 1, 2, and 3.

☐ 2. R.F. Gain Controls Pages 6-11

When automatic volume control systems are not used, an R.F. control is necessary. There are many types of gain controls—some vary the load while others change operating voltages. Of these, the C bias and the antenna-C bias controls are the most popular. Answer Lesson Question 4.

☐ 3. Automatic Volume Controls Pages 11-15

This is an explanation of the purpose and function of A.V.C. systems, how the A.V.C. voltage is filtered, and the importance of the time constant values of the filter. Answer Lesson Questions 5, 6, and 7.

☐ 4. Typical A.V.C. Circuits Pages 16-24

Here are descriptions of typical A.V.C. circuits. There are many types; some use separate tubes, and some have tapped voltage dividers. Answer Lesson Question 8.

☐ 5. Construction of Manual Volume Controls Pages 25-28

Few volume controls are made so that the resistance variation is linear. Most of them have either a left-hand or a right-hand taper. The proper taper is very important—sometimes more so than the resistance value itself. Study this practical section with great care. Answer Lesson Questions 9 and 10.

☐ 6. Mail Your Answers for this Lesson to N.R.I. for Grading.

☐ 7. Start Studying the Next Lesson.

MANUAL AND AUTOMATIC VOLUME CONTROLS

Why Volume Controls Are Needed

THE most important control in a radio receiver is unquestionably that which allows the listener to choose one desired station from the many which may be on the air at any one time. Next in importance is the *volume control*, which directly or indirectly controls the acoustical level or volume of the loudspeaker sound output. Volume controls are of two general types: 1, *automatic volume controls*; 2, *manual volume controls*. All radio receivers require manual volume controls, *even when equipped with automatic volume control*.

Automatic Volume Control. Automatic volume control (commonly abbreviated A.V.C.) keeps the output volume level of a radio receiver essentially constant despite variations in R.F. signal input voltage. These variations may occur while the radio receiver is tuned to a single station (fading) or while the receiver is being tuned from station to station.

The R.F. input signal voltages which modern receivers are called upon to handle may vary from 1 microvolt for low-power or distant stations to 1 volt for high-power local stations, and thus the strongest signal handled is a million times greater than the weakest signal. If the gain of the R.F. amplifier were *fixed* at a value sufficient for reproduction of the weakest signals, there would be *blasting* (excessive volume) when the set was tuned to a strong signal. A.V.C. counteracts this blasting by *raising the gain* of the R.F. amplifier for weak signals, and *lowering the gain* automatically and almost instantly for strong signals.

Blasting is particularly annoying

when the listener is tuning rapidly from station to station while searching for a desired program. Furthermore, blasting may be accompanied by *overloading* of the loudspeaker and of one or more stages in the receiver, with resulting distortion. A.V.C. prevents this overloading by reducing the gain of the R.F. amplifier for strong signals.

Programs received from distant and semi-distant stations, where the radio waves are totally or partially reflected from the sky before reaching the receiving antenna, are subject to *fading*. In other words, the strength of the signal at the receiving location varies considerably from minute to minute. A.V.C. can compensate for the effects of fading by raising and lowering the gain of the R.F. amplifier just enough to maintain the desired acoustical output, provided the signal does not become excessively weak. Automatic volume control is thus desirable in a radio receiver for these three important reasons: 1, *it prevents blasting*; 2, *it prevents overloading*; 3, *it minimizes fading*.

Manual Volume Control. A manual volume control is essential in a radio receiver for a number of reasons. Low volume may be desired when a musical program is used as atmospheric background while eating, reading, playing games, or carrying on conversation. Increased volume may be desired for news broadcasts, talks by important persons, radio plays, popular all-star broadcasts, symphonic music, or music for dancing; furthermore, some people can hear better than others, and the volume must be adjusted accordingly.

But what, exactly, is a volume con-

trol? To the average non-technical person, any control which permits him to change the volume of the sound coming out of the loudspeaker is a volume control. Radio men know,

rent swing over non-linear regions of the E_c-I_p characteristic of the tube. Because of this distortion, manual volume controls in receivers not having A.V.C. must be R.F. gain controls;

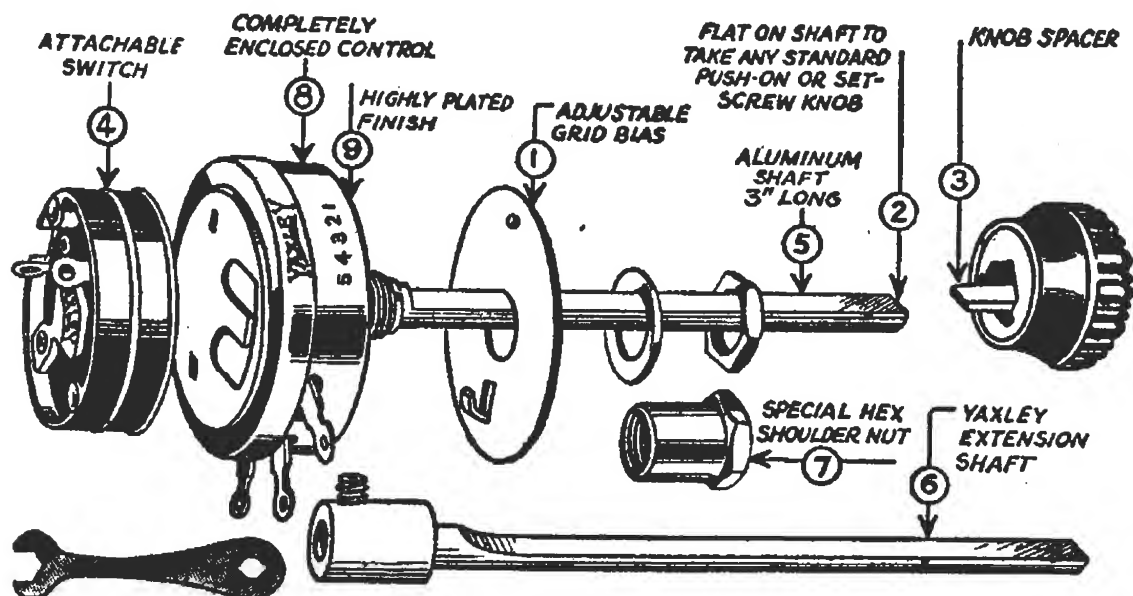


Fig. 1. Typical manual volume control with accessories (a unit made by the Yaxley Manufacturing Division of P. R. Mallory & Co., Inc.). A feature of this control is the adjustable grid bias plate (1) which permits adjusting the minimum resistance to 100, 200, 300, 400 or 500 ohms for fixed C bias purposes. Numbers on housing and indicating mark on plate tell which setting is used. With this plate removed, the control can be turned to zero resistance. The 3" shaft can be cut to any desired length with a file or hacksaw, or can be lengthened when necessary by using an extension shaft (6). A small metal spacer (3) is supplied with Yaxley controls for use with knobs designed for shafts having only 1/32" deep flats. The back cover plate of the control housing is easily removed to permit attachment of a power switch (4). The special nut (7) is used for mounting the controls on panels up to 3/4" thick. A small wrench like that shown is recommended for tightening this nut or the regular flat nut shown on the shaft, as pliers may wear off the corners of these nuts or scratch the panel.

however, that volume controls are either voltage controls or gain (amplification or sensitivity) controls. In receivers which have automatic volume control (commonly abbreviated as A.V.C.), the manual volume control is always an A.F. voltage control; in all other receivers the manual volume control is always an R.F. circuit control. (Regardless of whether the control is an R.F. or an A.F. type, the physical appearance will be almost the same. A typical control is shown in Fig. 1.)

There is a definite limit to the amount of signal voltage which can be handled by each stage in a radio receiver. Excessively high input voltage to a stage results in distortion, because high input signals make the plate cur-

they can then be adjusted to prevent overloading of *any* receiver stage.

TYPES OF MANUAL VOLUME CONTROLS

The manual volume controls found in radio receivers are of three types, which may be used either singly or in combination: 1, *R.F. voltage controls*, which reduce the voltage of the R.F. input signal either before it reaches the first R.F. amplifier stage or before it enters an R.F. stage which may overload; 2, *A.F. voltage controls*, which reduce the A.F. voltage output of the demodulator stage or reduce the A.F. voltage at some point in the A.F. amplifier; 3, *R.F. gain controls*, which reduce the gain (amplification) of an

R. F. amplifier stage either by varying the load on that stage or by varying the mutual conductance of the tube in that stage. We will now consider the advantages and disadvantages of each of these forms of manual volume controls as applied to practical radio receiving circuits.

R.F. VOLTAGE CONTROLS

R.F. voltage controls can either vary the R.F. voltage which is fed from the antenna to the input of the R.F. amplifier or can vary the R.F. voltage which is fed from one R.F.

movable contact arm connected to a third terminal (labeled *C*); the significance of these *R*, *L* and *C* (right, left and center) designations for these volume control potentiometers will be explained to you later. The value of the voltage fed to the following R.F. circuit depends upon the position of the movable arm of the potentiometer.

With the circuit of Fig. 2A, the fixed terminals of the potentiometer were connected to antenna and ground, and the variable tap on the potentiometer was connected directly to the grid of the first R.F. amplifier tube. The potentiometer thus con-

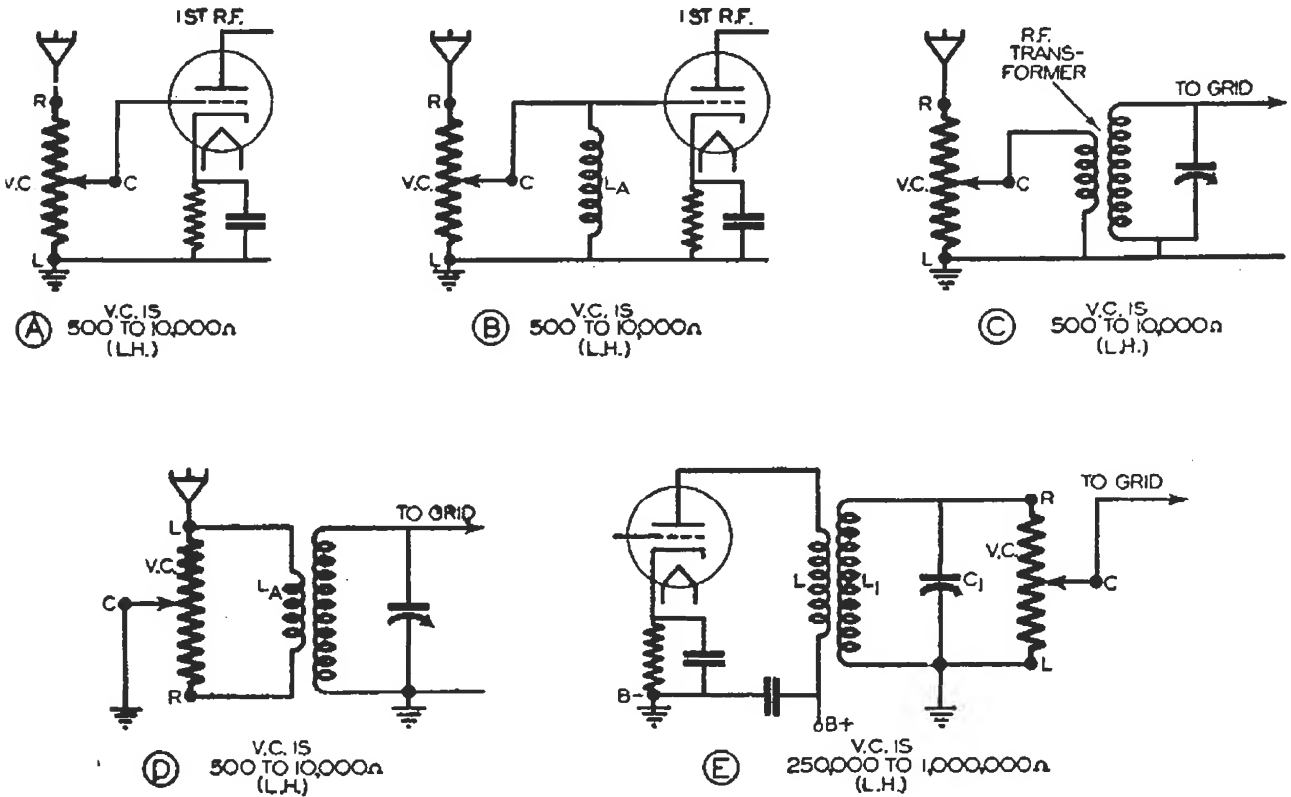


Fig. 2. Typical manual volume control arrangements which vary the amount of R.F. voltage transferred from one circuit to another. The resistance values indicated for V.C. are maximum values; the minimum resistance in each case is zero. The designations *R*, *L*, *C*, R.H. and L.H. are explained later in this text-book.

amplifier stage to another. These controls were widely used in older receiver circuits for the purpose of controlling volume, the antenna circuit control having been the more popular.

Five typical R.F. voltage control circuits are shown in Fig. 2. As you can see, the control device in each case was a potentiometer with two fixed terminals (labeled *R* and *L*), and a

trolled the R.F. voltage which was applied to the grid of this tube. This circuit had no selective or signal-boosting properties; therefore, only the characteristics of the antenna determined which signals would be favored. The antennas used at the time were generally of such a length that they were in resonance at the higher frequencies in the broadcast band,

and consequently these higher frequencies were favored.

To make the simple antenna circuit volume control of Fig. 2A respond equally well to low and high frequencies, inductance L_A was connected between grid and cathode of the first R.F. tube in the manner shown in Fig. 2B. The inductance and distributed capacity of coil L_A acted together to form a parallel resonant circuit whose resonant frequency was in the lower region of the broadcast band. This resonant circuit acted as a high impedance to low frequency signals, developing maximum R.F. voltage for transfer to the grid of the tube, and acted as a capacitive reactance path to ground (a shunting capacity) for higher frequency signals. By choosing the proper ratio of inductance to capacity for coil L_A , it was possible to make the antenna circuit respond uniformly to both low and high frequencies in the broadcast range.

The volume controls shown in Figs. 2A and 2B worked well in receivers located at a distance from powerful broadcast stations, but in the vicinity of a powerful station the capacity path between the leads and parts of the volume control was sufficient at radio frequencies to transfer the signal of the local station to the grid of the first tube at all volume control settings. When the volume control was turned up to receive a weak signal, the signal of the local station overloaded the first R.F. amplifier tube, making this tube act as a detector which modulated the weak signal with the program of the strong signal; cross-modulation resulted, with both the desired and the undesired programs being reproduced by the loudspeaker.

The next move of the radio receiver designer was to provide selectivity for the antenna circuit in order to coun-

teract cross-modulation effects. One of these selective circuits is shown in Fig. 2C. As you can see, the voltage output of the volume control was fed into the primary of an R.F. transformer, and the resulting R.F. current induced a stronger R.F. voltage in the tuned secondary of this transformer for transfer to the grid of the first tube. The chief drawback of this circuit was the fact that whatever resistance existed between terminals C and L of the potentiometer was reflected into the resonant circuit as a resistance; this made selectivity very poor at low volume control settings.

The modified potentiometer connection shown in Fig. 2D gave improved selectivity. Note that the variable tap of the potentiometer was grounded and that the entire potentiometer resistance was connected across the primary of the R.F. transformer. This resulted in a constant and high resistance being reflected into the resonant circuit, keeping the selectivity essentially constant. Antenna and ground connections were made to points L and C on the potentiometer. As the resistance between these two points was increased, more of the antenna current flowed through coil L_A and therefore a higher R.F. voltage was induced in the resonant circuit.

The usual form of R.F. voltage control used between two R.F. stages was that shown in Fig. 2E. Here the voltage developed across series resonant circuit L_1-C_1 was fed to the two fixed terminals of the volume control potentiometer, and the variable tap of the potentiometer was connected directly to the grid of the following R.F. amplifier tube. The potentiometer resistance was generally between .25 megohm and 1 megohm, so the load placed upon the resonant circuit by the volume control was negligible. One disadvantage of this circuit was the fact that body capacity, such as

placing the hand near the volume control, tended to detune the circuit; this made it necessary to use a long shaft of insulating material between the potentiometer and its control knob. Furthermore, this volume control and the antenna circuit R.F. voltage con-

(acting as load). When an audio transformer is used at the input, a common form of A.F. voltage control is that shown in Fig. 3A. Here audio transformer T couples the A.F. signal source to volume control potentiometer $V.C.$. In any

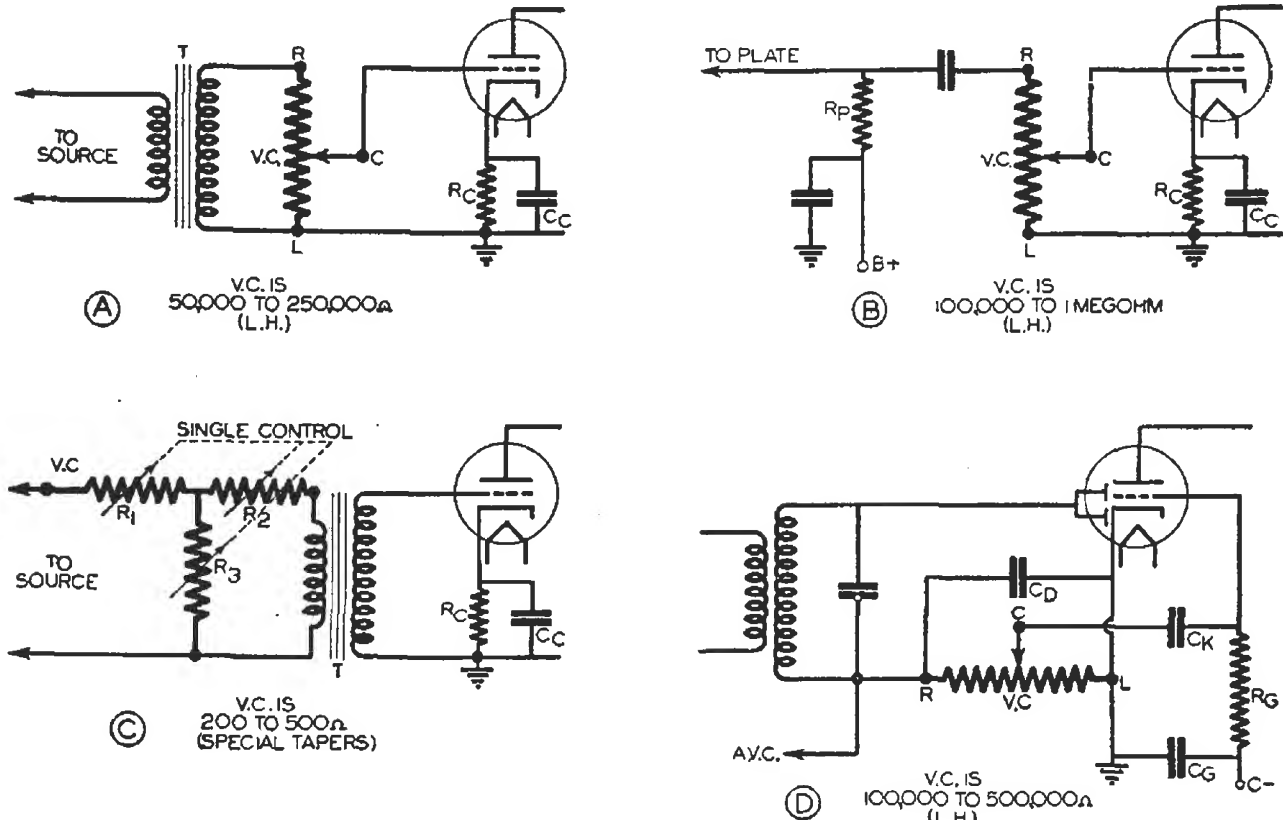


Fig. 3. Typical manual volume control arrangements which vary the amount of A.F. voltage transferred from a source of A.F. voltage to a following circuit.

trols were quite noisy, for they controlled low R.F. voltages in high-gain circuits.

A.F. VOLTAGE CONTROLS

Several different ways of connecting manual volume controls into audio frequency amplifier circuits are shown in Fig. 3. Controls such as these are essential in the audio amplifiers of public address systems, in intercommunicating systems, in electric phonographs and in all radio receivers which employ A.V.C. in the R.F. amplifier. Basically, an A.F. voltage control varies the amount of audio frequency voltage which is fed from one circuit (acting as source) to another

circuit where the signal source has a high impedance, approaching that of the volume control, the transformer may be omitted and the source connected directly to terminals R and L of the potentiometer. Any desired portion of the voltage applied across the potentiometer is fed to the grid and cathode terminals of the following A.F. amplifier tube.

With resistance-capacitance coupled audio amplifiers, the arrangement of the A.F. voltage control is as shown in Fig. 3B.

When inserting a volume control in the input of a circuit which is acting as a load for an A.F. signal source, the volume control must not alter the impedance match between the source

and load. In cases like this, special constant-impedance volume controls or pads are used; these consist of two or more variable resistors which are adjusted simultaneously. The circuit in Fig. 3C is an example; here a so-called T-pad volume control having three variable resistors (this name results from the fact that the resistors are arranged to form the letter "T") is so connected that the resistance across the input terminals and the output terminals of the T-pad remains constant (at 200 ohms for a 200-ohm T-pad or at 500 ohms for a 500-ohm T-pad) regardless of the setting of the control knob. Only the A.F. voltage across the output terminals of the T-pad varies with the control knob setting. This subject is covered in greater detail in advanced lessons; for the present it is sufficient for you to know

what this type of A.F. voltage control is and why it is used.

A type of A.F. voltage control which you will constantly encounter in radio receivers using diode detectors and A.V.C. is shown in Fig. 3D. Here the volume control serves as load for the diode demodulator or second detector. The R.F. signal is by-passed around this volume control by condenser C_D ; this condenser also serves to smooth out the rectified R.F. voltage, producing the desired A.F. signal across the volume control. The A.F. voltage between points L and C is fed to the grid of the first A.F. amplifier tube (in the same envelope as the diode detector) through D.C. blocking condenser C_K . Other types of A.V.C. circuits in which manual volume controls are incorporated will be considered later in this book.

R. F. Gain Controls

Volume Controls Which Vary the Load in an R.F. Circuit. In the earliest battery-operated receivers, volume was controlled simply by varying the filament current of one or more tubes in the receiver. With the advent of A.C.-operated receivers, volume control became a more difficult problem, for varying the filament currents in heater type tubes did not give a satisfactory control over volume.

One of the first manual volume control schemes used in A.C. receivers was that shown in Fig. 4, which involved placing a variable resistor across the plate load resistance of an R.F. stage. Without this variable resistor the tuned secondary R.F. transformer made up of L_1 , L_2 and C_2 offered a definite load in the plate circuit of tube VT_1 , and the stage consequently had a definite amplification or gain. Shunting a volume control across L_1

permitted reduction of the plate load impedance and the gain to any desired lower value. Because of the fact that decreasing the load impedance increased the curvature of the E_c - I_p curve, making strong R.F. signals swing over non-linear portions of the curve, this scheme could be used only in the plate circuit of an R.F. stage which handled low R.F. voltages. This method of controlling volume also served as a control on regeneration, for it varied the A.C. plate voltage and thus varied the feed-back voltage.

Volume Controls Which Vary the Screen Grid Voltage in an R.F. Stage. The amplification of a vacuum tube amplifier can be controlled to a considerable extent by varying the D.C. voltages applied to the electrodes of the vacuum tube used in the stage. Any change in electrode operating voltages which affects the mutual con-

ductance of the tube will also affect the amplification provided by the stage. This is true because, as you will recall, mutual conductance is equal to A.C. plate current divided by A.C. grid voltage. Reducing the A.C. plate current therefore reduces the mutual

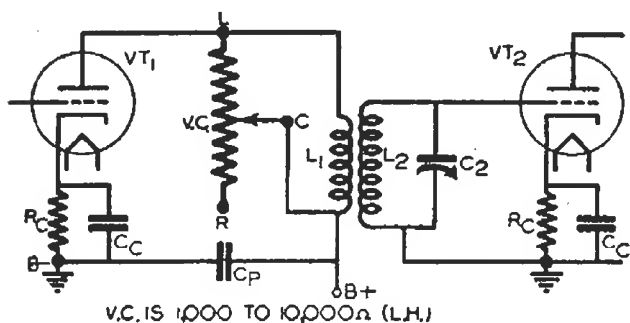


Fig. 4. This volume control varies the impedance of the load in an R.F. circuit and thus varies the gain of the R.F. amplifier.

conductance and, at the same time, reduces the A.C. voltage which is developed across the plate load for transfer to the following stage.

As a general rule, reducing the D.C. plate voltage, reducing the D.C. screen grid voltage or increasing the negative C bias voltage will reduce the mutual conductance of a tube. Making the suppressor grid negative with respect to the cathode and increasing its negative voltage will also decrease the mutual conductance. It is not customary, however, to vary the suppressor grid voltage for the reason that very large changes are required in voltage in order to secure any appreciable reduction in mutual conductance.

The usual method for controlling the screen grid voltage was that shown in Fig. 5A; the volume control potentiometer was made part of a voltage divider connected across the plate supply source, with resistor R_L serving to determine the maximum screen grid voltage. Condenser C_s, the screen bypass condenser, also helped to prevent noisy volume control action, for it shunted the L-C section of V.C. and thus by-passed to ground any current

impulses created by a varying contact resistance at C.

Volume Controls Which Vary the Plate Voltage of an R.F. Amplifier Tube. A method used in early battery receivers for varying the plate voltage of a tube as a means of controlling volume was that shown in Fig. 5B, where a variable resistor was placed in series with the plate supply voltage and the R.F. plate load. This method was advantageous in that it did not place any unnecessary drain upon the B batteries, but had the disadvantage that a very high-resistance rheostat, which burned out easily, was required.

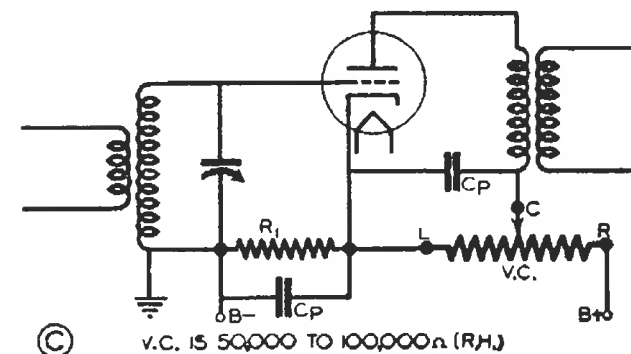
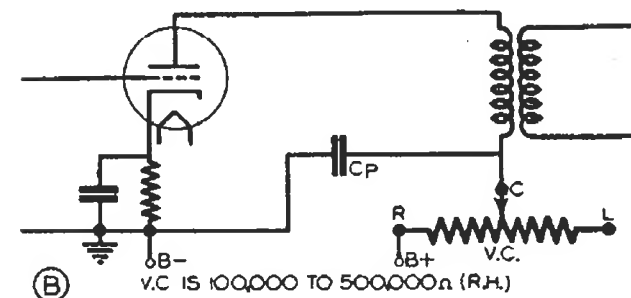
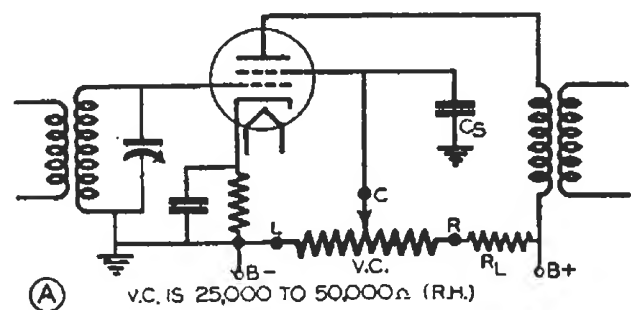


Fig. 5. Typical manual volume control arrangements which vary the mutual conductance of an R.F. amplifier tube by varying the screen grid voltage (A) or the plate voltage (B and C).

Plate voltage can also be controlled by using a potentiometer connected across the plate voltage supply in the manner shown in Fig. 5C. With this potentiometer across the B battery at all times, there was naturally a higher current drain than in the case of Fig. 5B, but the potentiometer was lower in resistance, making possible a more rugged design and consequently reducing the tendency to burn out.

Unfortunately, these methods of controlling volume by varying screen grid and plate voltage did not prove entirely satisfactory. Reducing these electrode voltages any reasonable amount affected the dynamic E_g-I_p characteristic of the tube enough to cause distortion at low volume control settings. These circuits were quickly replaced by the still popular C bias method of volume control, which will now be considered.

Volume Controls Which Vary the C Bias Voltage of an R.F. Amplifier Tube. The most effective way of varying the mutual conductance of a tube in order to control volume is by *varying the control grid voltage* (the C bias voltage). This method of controlling volume proved so satisfactory and came into such widespread use that tube designers developed special remote cut-off tubes, first the *variable mu screen grid tube* and later the *super-control pentode tube*, which gave even better results. These tubes allowed the A.C. grid voltage to swing over an essentially linear portion of the dynamic E_g-I_p characteristic curve at all volume control settings. A number of typical C bias volume control circuits are shown in Fig. 6; although triode tubes are indicated for simplicity, the circuits also apply to screen grid and pentode tubes.

A scheme widely used in early battery receivers for varying the C bias voltage was that shown in Fig. 6A, where the negative C bias voltage was

increased and the filament current was reduced simultaneously (by increasing the resistance of volume control V.C.) in order to reduce the mutual conductance of the tube. When the filaments of several tubes are in parallel and the grid return lead for each tube circuit is grounded, a volume control such as this will affect all such parallel-fed circuits.

Another C bias voltage control for battery receivers, used when filament voltage was fixed in value, is that shown in Fig. 6B. Here potentiometer V.C. and resistor R_1 were placed in series across a C battery which was connected with the indicated polarity. The value of R_1 must be low enough to develop the minimum C bias required for the circuit. (A high-resistance load on the C battery will make it last longer than the B batteries; with normal C bias and low B voltages, certain tubes will distort severely. For this reason, values for V.C. and R_1 were chosen which were low enough to make the B and C batteries run down at approximately the same rate.) Switch SW opened both the A and C battery supply circuits in order to prevent current drain when the receiver was not in use.

The basic C bias voltage volume control for heater type tubes is that shown in Fig. 6C. The volume control is placed in series with the usual cathode bias resistor R_C , with condenser C_C connected between the cathode and the movable tap of the volume control. Increasing the resistance setting of the volume control increases the C bias voltage and therefore reduces volume; resistor R_C determines the minimum C bias voltage. The chief disadvantage of this circuit is that as the negative C bias voltage is increased, the plate current which flows through the cathode resistor combination is greatly reduced, counteracting the effect of the volume control. For example, if a cathode bias resistance

of 600 ohms gives a 3 volt negative bias, it may be necessary to increase this resistance to as much as 25,000 ohms in order to secure three times as much bias voltage (—9 volts).

Where the movable tap of the volume control is grounded, as in Fig. 6C, receiver manufacturers will often use a potentiometer in which the movable tap or middle terminal *C* is grounded internally to the metal shaft of the

made essentially independent of the plate current. The volume control now has greater control over the *C* bias voltage and can be considerably lower in value than in the case of Fig. 6C.

In some receivers the volume control is actually a part of the power pack voltage divider system or is an additional voltage divider across a part of the main voltage supply in the manner shown in Fig. 6E. Here volume

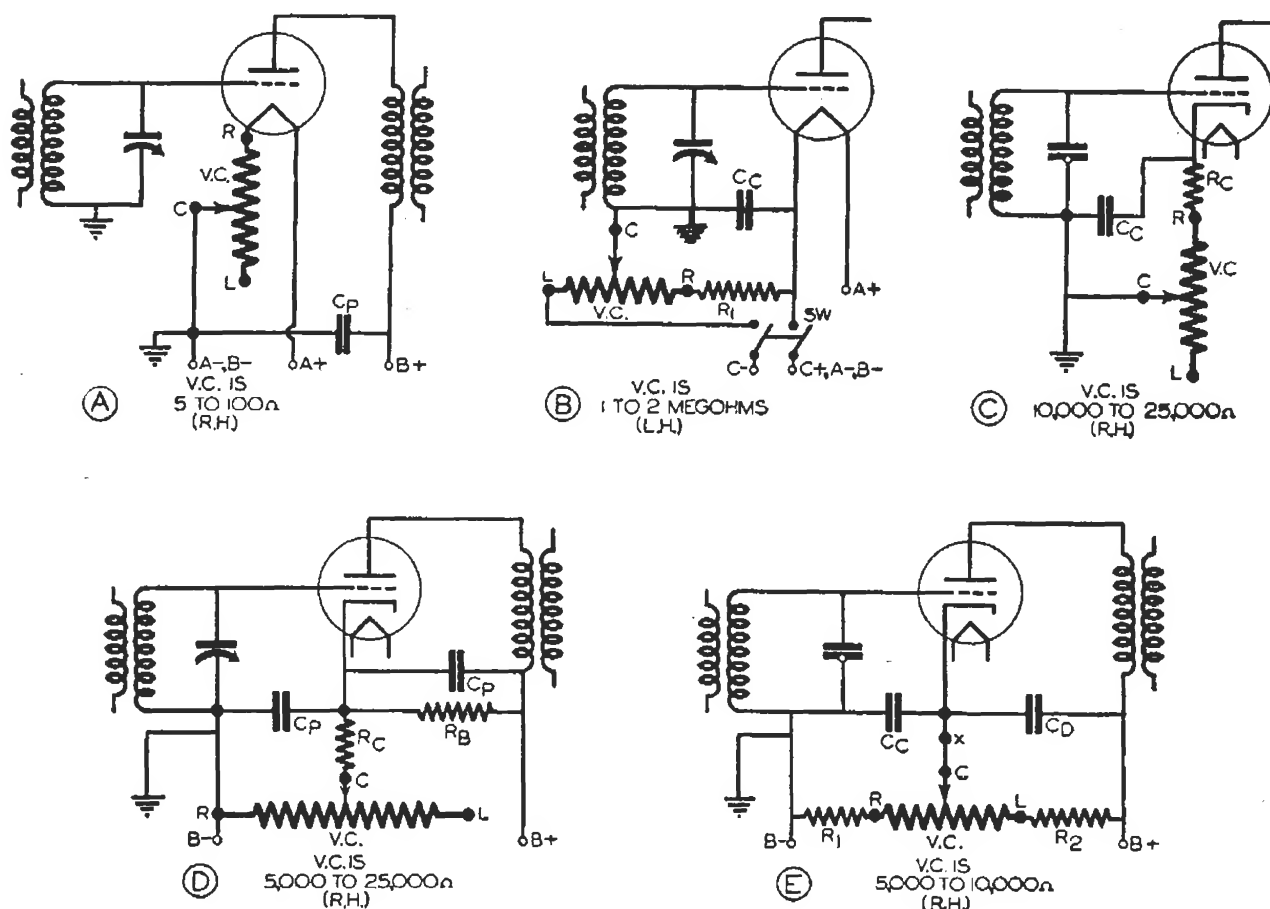


Fig. 6. Typical manual volume control arrangements which vary the mutual conductance of an R.F. amplifier tube (thereby varying the gain of the R.F. amplifier) by varying the *C* bias voltage applied to the control grids of one or more R.F. tubes.

control. This eliminates the need for making a soldered connection to the middle terminal, for mounting the potentiometer on the metal chassis automatically grounds the housing.

An improved *C* bias volume control arrangement is shown in Fig. 6D. By having between the plate voltage lead and cathode a bleeder resistor R_B which forces or "bleeds" a current through the *C* bias resistor R_C at all times, the volume control current is

control potentiometer *V.C.* varies the voltage between the cathode and the *B*— terminal, with resistor R_1 determining the minimum *C* bias voltage and resistor R_2 determining the maximum *C* bias voltage. The total resistance of R_1 , *V.C.* and R_2 in series across the power pack determines the value of bleeder current which flows at all times. Both the plate current of the tube and the bleeder current flow through R_1 and the *R*—*C* section of the

volume control, producing a C bias voltage which is dependent upon the position of movable tap C.

Volume Controls Which Vary Both the Antenna Input and C Bias Voltages. We cannot pass over C bias

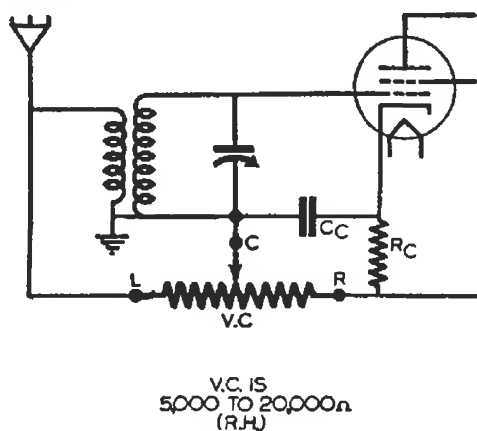


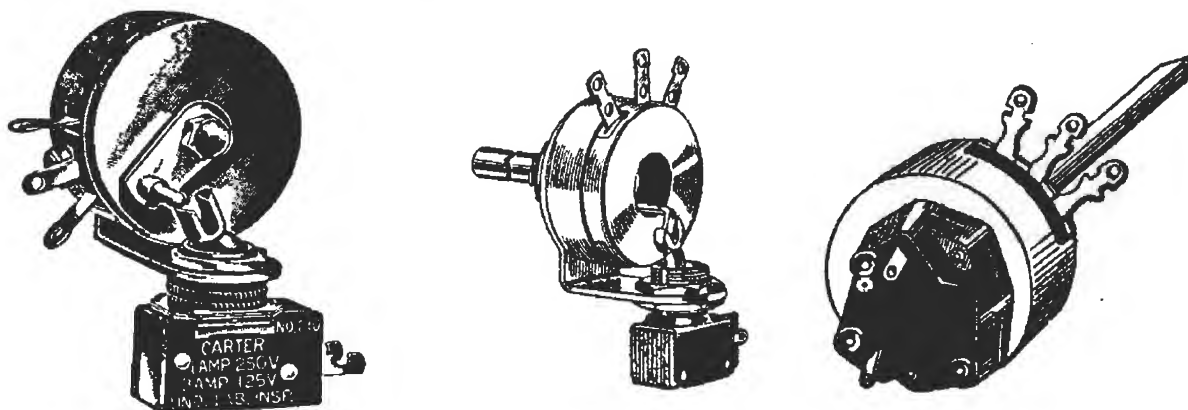
Fig. 7. A manual volume control arrangement which varies both the antenna input R.F. voltage and the C bias voltage of the first R.F. stage in order to change the R.F. amplifier gain.

voltage volume controls without pointing out that with the earlier triode and screen grid tubes, increasing the negative C bias beyond a certain point changed an R.F. amplifier stage into a

two types of volume control circuits in solving this problem.

One typical combination volume control circuit is shown in Fig. 7. Here fixed resistor R_c controls the minimum C bias voltage and hence the maximum amplification of the stage. That section of the volume control potentiometer between points C and R also serves as cathode bias resistor, while the remaining section shunts the input transformer primary winding. Moving contact C away from point R increases the C bias voltage and at the same time reduces the resistance across the primary winding, thus giving a double reduction in R.F. signal gain.

Variations of Manual Volume Control Circuits. You are now familiar with the important basic manual volume control circuits. Of course you will encounter many variations of these circuits in radio receivers, but as a rule these variations will be easily recognized as one of the types which you have studied.



Today it has become an almost universal practice among receiver designers to make the manual volume control or some other manual control serve also as an on-off switch. Earlier forms of dual potentiometer-switch arrangements appear at the left (a Carter unit) and in the center (a Yaxley unit); in both of these, rotation of the control knob to the extreme counter-clockwise position caused an arm on the control shaft to flip the toggle switch to its off position. At the right is a modern universal replacement volume control (a Philco unit) with a special power switch attached to its cover plate for this same purpose.

detector, with resulting modulation distortion and cross-modulation on strong signals. With variable mu screen grid tubes and super-control pentode tubes this is naturally no longer a problem, but it will be of interest to see just how receiver manufacturers combined

Before beginning our study of automatic volume control circuits, we want to state definitely that with A.V.C.-controlled receivers, the manual volume control must be *in the audio system*, except in those cases where the manual control is of a type which

changes the effectiveness of the A.V.C. control. You can readily understand that any attempt to reduce the R.F. output of the R.F. amplifier manually

would simply cause the A.V.C. system to increase the amplification and counteract the change in the manual volume control setting.

Automatic Volume Controls

A.V.C. action is basically simple. When the carrier level of the R.F. input signal is excessively high, A.V.C. lowers the gain of the R.F. amplifier by increasing the negative C bias voltage on one or more R.F. amplifier tubes. This is accomplished automatically by rectifying the R.F. carrier signal, then filtering out all but the resultant D.C. voltage, whose value is always proportional to the R.F. carrier level. This D.C. voltage is so applied to the grids of the R.F. amplifier tubes that *increases* in carrier level make the grids *more negative*. The R.F. amplifier gain is thus reduced enough to keep the R.F. amplifier output level essentially constant and prevent overloading of any tubes. Likewise, *reductions* in input carrier level result in *less negative* C bias voltages and greater amplification.

It is clearly impossible for A.V.C. to maintain the R.F. carrier level perfectly constant at the output of the R.F. amplifier, for it is the change in this level which produces the change in negative C bias voltage required for automatic volume control. With proper design, however, A.V.C. can keep the carrier level constant enough for all practical purposes. Exact control of carrier level is not required, for the output voltage of a receiver can be increased or decreased about 40 per cent before the change can even be detected by the human ear. When working with A.V.C.-controlled circuits, then, never depend upon your ears as a judge of performance; always use an output meter or some other type of indicator.

The action of a receiver having A.V.C. is best represented by overload curves like those in Fig. 8, which are obtained by plotting the R.F. input voltage of the receiver against the A.F. output voltage of the demodulator or second detector. Curve 1 in Fig. 8 represents the overload characteristics of a receiver not having A.V.C. Notice that overloading takes place at an R.F. input voltage of about 100 microvolts

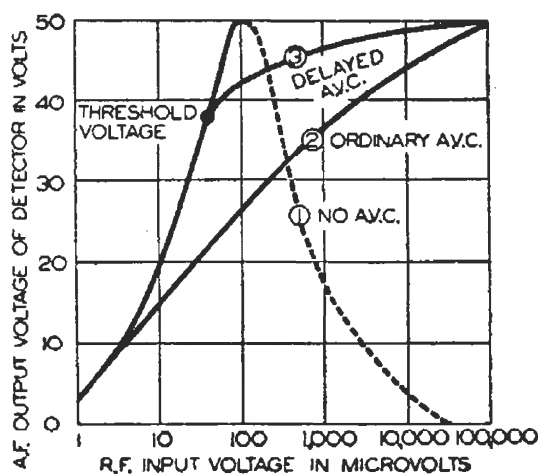


Fig. 8. Overload characteristic curves for three different superheterodyne radio receivers, obtained by feeding various R.F. input voltages into each receiver (the manual volume control being set for maximum volume) and measuring the A.F. output voltage of the second detector. Curve 1 is for a sensitive receiver which does not have A.V.C. Curve 2 is for the same receiver with ordinary A.V.C. added. Curve 3 is for the same receiver with delayed A.V.C. added. These curves illustrate receiver performance in general, and will naturally vary greatly with different receivers.

in this particular example. This is shown by the output falling off when the input is increased further. When this receiver is equipped with A.V.C., its overload characteristic is represented by curve 2. You can readily see

that with A.V.C., the receiver will handle all carrier signal levels below 100,000 microvolts (.1 volt) without overloading. On the other hand, however, this A.V.C. curve shows that the sensitivity of the receiver will be considerably lower with A.V.C. than without it for medium-strength signals. (R.F. input voltages in the region between about 10 and 100 microvolts do not deliver as much output.) Let us see how this drawback of A.V.C. is overcome in some receivers.

Delayed A.V.C. Since ordinary A.V.C. circuits prevent the maximum amplification of the receiver from being effective at low carrier levels, and since A.V.C. action is not particularly required at these low carrier levels since they cannot possibly cause overloading, the receiver designer simply arranges the A.V.C. system so it is inactive until the carrier level reaches a definite and fairly high value. This arrangement, which utilizes the full sensitivity of the receiver at low carrier levels, is known as *delayed A.V.C.* The *R.F. input voltage level at which A.V.C. action begins* is called the *threshold point* or the *threshold voltage*. The overload characteristic curve for a receiver having delayed A.V.C. is represented by curve 3 in Fig. 8. Notice that it follows curve 1, that for a receiver without A.V.C., up to the threshold voltage, after which it levels out and effectively prevents overloading.

Since the A.F. output voltage of the second detector in a receiver having delayed A.V.C. is quite high at the threshold point, further increases in output voltage should be prevented as much as possible. To do this, the negative C bias voltage produced by A.V.C. action should be applied to as many R.F. tubes as possible. If even this is insufficient, the A.V.C. voltage can be amplified by an extra vacuum tube stage, giving what is known as an

amplified delayed A.V.C. circuit.

Definitions. Those R.F. amplifier stages in an A.V.C. receiver which are to vary in gain as the incoming carrier level varies are called the *A.V.C.-controlled stages* or simply the *controlled stages*. The tubes in these controlled stages are called *A.V.C.-controlled tubes* or simply *controlled tubes*. The vacuum tube or tube section which converts the amplified modulated R.F. carrier into a D.C. voltage suitable for A.V.C. purposes is called the *A.V.C. tube* or *A.V.C. stage*, and the D.C. voltage is called the *A.V.C. voltage*. The A.V.C. voltage may be produced as a part of the action of demodulation, or may be produced independently by an extra stage in the receiver.

SIMPLE DIODE DETECTOR—A.V.C. CIRCUITS

A simple diode demodulator or detector circuit like that shown in Fig. 9A is not only capable of separating the modulation signal from the R.F. carrier, but can also produce the negative C bias voltage required for A.V.C. purposes. The modulated R.F. carrier signal at points 1 and 2 in the final I.F. amplifier stage passes through the final resonant circuits, L_p-C_p and L_s-C_s , and is applied directly to the plate and cathode of diode detector tube VT_2 . Condenser C_D offers no opposition to this signal, for it has a low reactance at radio frequencies.

The modulated R.F. carrier is rectified by the diode tube, since this tube allows current to pass only in one direction; the wave form of the current passing through this tube is therefore like that shown in Fig. 9B. The charging and discharging action of condenser C_D on this pulsating current passing through R_D serves to filter out the R.F. variations, making the voltage across R_D have the wave form shown in Fig. 9C. Observe that this wave is made up of a D.C. component

which is proportional to carrier level and an A.C. component which is proportional to the percentage of modulation and the carrier level. If the values of C_D and R_D are properly chosen, this A.C. component will be an exact reproduction of the audio or video intelligence signal. This intelligence signal is fed into a low frequency amplifier (not shown in circuit) for further amplification by coupling the grid of the first low frequency amplifier stage to

the D.C. component of the voltage between terminals 3 and 4 is proportional to the level of the modulated R.F. carrier, these terminals may be used as a source for the desired A.V.C. voltage provided that the low frequency component is removed. Application of an A.F. signal to the grid of a controlled tube would place extra modulation on the carrier, a clearly undesirable condition. For this reason, it is necessary to filter the A.V.C. voltage in a radio

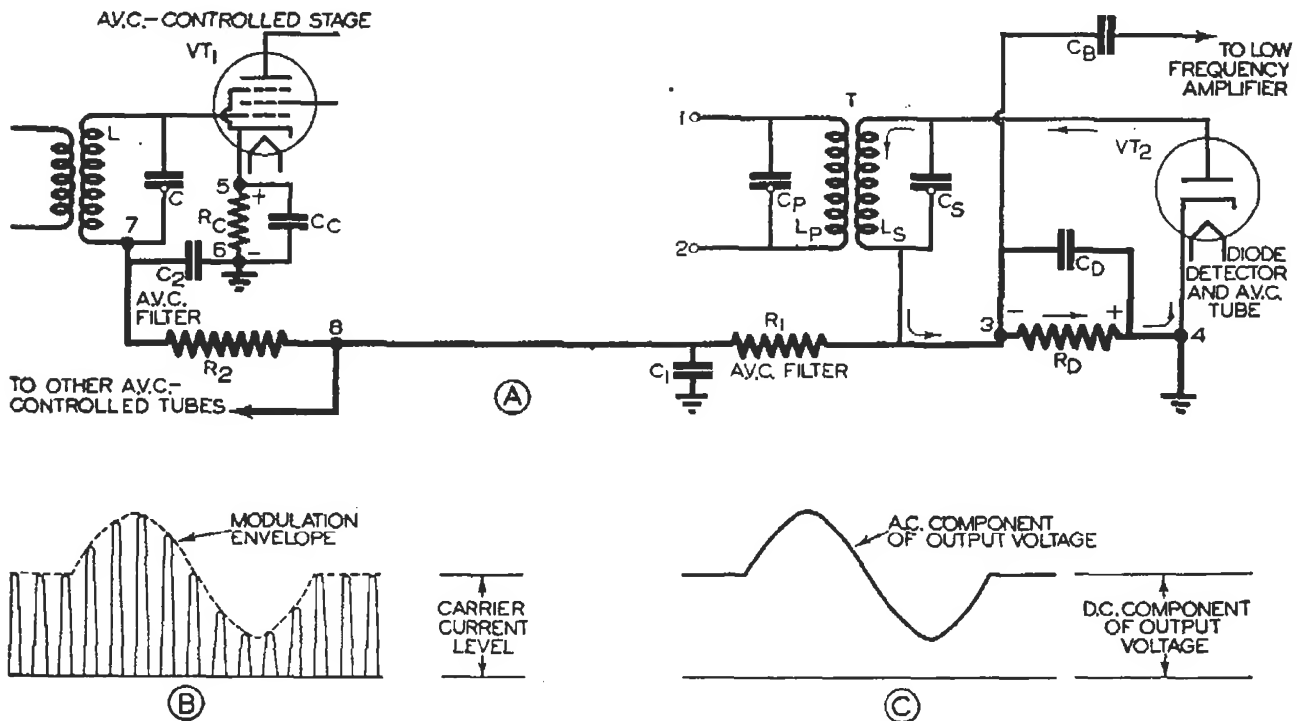


Fig. 9. These diagrams, together with the accompanying text, give the complete story of how an A.V.C. voltage can be produced by a simple diode detector, how this voltage can be filtered, and how the voltage is applied to an A.V.C.-controlled R.F. stage.

point 3 on resistor R_D through blocking condenser C_B , which blocks out the D.C. voltage component. The circuit is completed through the chassis.

Let us trace D.C. electron flow in the diode detector circuit of Fig. 9A. We start with the diode tube, for we know that electrons flow from the cathode to the plate. These electrons flow through coil L_s in the direction indicated by the arrows, then enter terminal 3 of resistor R_D , making this terminal negative with respect to the other resistor terminal (4); terminal 3 is therefore negative with respect to chassis or ground. Furthermore, since

receiver in order to keep the A.F. signal voltage out of the A.V.C.-controlled stages.

Filtering the A.V.C. Voltage. The fact that the control grids of R.F. amplifier tubes are negative, so that no D.C. grid current is drawn from the A.V.C. circuit, simplifies the problem of filtering the A.V.C. voltage. In Fig. 9A you will find two A.V.C. filters connected between point 3, at which both D.C. and A.F. components of voltage exist, and point 7 in the grid circuit of an A.V.C.-controlled stage, at which only the D.C. component of voltage is desired. These A.V.C. filters keep the

A.F. signal voltage out of the A.V.C.-controlled stages of the R.F. amplifier.

Let us consider first the A.V.C. filter made up of C_1 and R_1 . Notice that R_1 - C_1 form a low-pass filter. The series element R_1 offers a far greater opposition to alternating current than C_1 does, so most of the A.F. is dropped across R_1 . Resistor R_2 and condenser C_2 in the second A.V.C. filter provide additional filtering in the same way, making the voltage at point 7 a practically pure D.C. voltage. Condensers C_1 and C_2 naturally have no effect upon the D.C. voltage, and since no direct current flows through the filter circuit, resistors R_1 and R_2 likewise have no effect upon the value of D.C. voltage at point 7.

The flow of plate current through resistor R_0 and condenser C_0 in the A.V.C.-controlled stage containing tube VT_1 produces across R_0 a D.C. voltage which makes point 6 negative with respect to the cathode; this is ordinary automatic C bias action. The voltage drop across cathode resistor R_0 is applied to the grid of tube VT_1 through the chassis path between grounded points 6 and 4, then through R_D , R_1 , R_2 and coil L in turn, thus placing on the grid its normal C bias.

When an R.F. carrier signal is present in the receiver, the D.C. component of voltage produced across R_D acts in series with, and aids, the automatic C bias voltage. Thus the A.V.C. voltage and the automatic C bias voltage add together to make the grid of each controlled tube more negative than would be the case without A.V.C. An increase in carrier signal level boosts the D.C. component of voltage across R_D , driving the grid of each A.V.C. controlled tube more negative and thereby reducing the amplification of each tube sufficiently to keep the signal voltages in all stages of the receiver below the overload values. In an A.V.C. system a condition of equilibrium exists where

the carrier level at the detector is kept just enough above the desired constant value to provide the required A.V.C. voltage.

Condenser C_2 in the circuit of Fig. 9A has another important task, that of providing a path to point 6 for the R.F. voltage developed across coil L . If this condenser were omitted, the R.F. current would have to flow through R_2 and C_1 to ground; R_2 would naturally offer considerable opposition to the flow of R.F. current, and there would also be the possibility that R.F. current would stray into circuits where it could cause interference and undesirable feed-back. Since the reactance of C_2 is less than the reactance of the R_2 - C_1 path to ground, R.F. currents will take the C_2 path to ground.

The A.V.C. filter system made up of C_2 and R_2 can be and often is omitted, leaving C_1 and R_1 to do the A.F. filtering and R.F. isolating, particularly when only one tube is being controlled by A.V.C. When several R.F. amplifier tubes are being controlled, it is customary to use an A.V.C. filter similar to R_2 and C_2 in each controlled stage making connections from each controlled stage to point 8. This serves to isolate the tube circuits from each other, preventing undesirable feed-back.

TIME CONSTANT OF THE A.V.C. SYSTEM

An A.V.C. system must prevent blasting when a receiver is tuned suddenly from a weak to a strong signal and must also compensate for more or less rapid fading effects. For this reason we are interested in knowing exactly how long it takes for the A.V.C. system to get into action when the R.F. carrier level is suddenly changed.

The D.C. component of voltage across R_D in Fig. 9A changes immediately after a change in carrier level

but it takes a certain amount of time for condenser C_1 in the first A.V.C. filter to charge or discharge to a new voltage value through R_1 .

The amount of time delay introduced by A.V.C. filter R_1 - C_1 depends upon the ohmic value of resistor R_1 and the capacity of condenser C_1 ; this time, when expressed in seconds, is known as the *time constant* of the A.V.C. filter system, and can be computed quite easily. In the case of Fig. 9A, this can be done by multiplying the ohmic value of R_1 in megohms by the capacity of C_1 in microfarads. The result will be the time constant of the circuit in seconds, or the time required for the A.V.C. voltage to reach approximately 63% of its final new value after a change in carrier level. (It is standard practice among engineers to specify time constants for 63% of the total change, this having proved more convenient than a time constant based upon a total change.) The A.V.C. filter made up of R_2 and C_2 likewise introduces a time delay, which *increases* the time constant of the entire A.V.C. filter system. Remember—the time constant of an A.V.C. filter system is determined by *the values of the resistors and condensers in the A.V.C. filter system*.

A low time constant is naturally desirable in order to make the A.V.C. system respond as rapidly as possible to changes in carrier level; this can be secured by making the values of R_1 , R_2 , C_1 and C_2 low, but doing this impairs the filtering action which is so essential to the operation of an A.V.C. system. Receiver design engineers

therefore resort to a compromise which uses filter system parts large enough to provide satisfactory filtering and at the same time small enough to provide a sufficiently short time delay. A time constant of *one-fifth to one-tenth of a second* for the A.V.C. filter system is considered satisfactory by most engineers for the prevention of blasting and the reduction of fading.

The value for condensers C_1 and C_2 in an A.V.C. filter system have become essentially standard among receiver designers. A capacity of .1 mfd. for C_1 and .05 mfd. for C_2 are generally used, for these condensers are inexpensive and at the same time have a reactance of less than 20 ohms for any I.F. or R.F. signal which may be attempting to flow from resonant circuit L - C into the diode load. A .1 mfd. condenser, when used with a 1 megohm resistor, gives a time constant of one-tenth second. The filter action of these parts is such that they will reduce the strength of the lowest audio frequency signal which tries to get into the R.F. and I.F. amplifiers about 100 times. Two of these filter combinations would increase the time constant to one-fifth second and would increase the audio frequency filtering factor to 10,000 times. Ordinarily you will find that the values of resistors R_1 and R_2 range from .1 to 1 megohm, while condensers C_1 and C_2 range from .02 to .1 mfd. Do not be surprised, however, if you occasionally encounter quite different values than these; circuit conditions and the opinions of engineers vary widely. Changing the values of A.V.C. filter resistors or condensers affects the speed of A.V.C. action.

Typical A.V.C. Circuits

Automatic volume controls are usually found only in superheterodyne receivers. As we will soon see, A.V.C. systems reduce the selectivity somewhat, and only superheterodynes have enough to spare. A.V.C. was tried on a few early high-gain T.R.F. receivers, but today, the only T.R.F. sets are inexpensive midgets which do not have this feature.

The sections of a superheterodyne receiver which are usually A.V.C.-controlled are as follows: 1, The R.F. amplifier, which amplifies the incoming modulated R.F. carrier signal; 2, the mixer-first detector, which mixes the incoming R.F. signal with the local os-

trolled. If there are three I.F. stages, the second is also A.V.C.-controlled. The final I.F. stage ordinarily has no A.V.C. control, or the control on this stage may be greatly reduced. This is because each succeeding stage handles greater and greater modulated carrier signal levels, and driving the C bias of a heavily loaded stage highly negative results in amplitude distortion and even partial or complete cut-off of the signal.

The more stages which are A.V.C.-controlled, the more uniform will be the receiver output and the less chance there will be for overloading. With these facts in mind, let us examine a

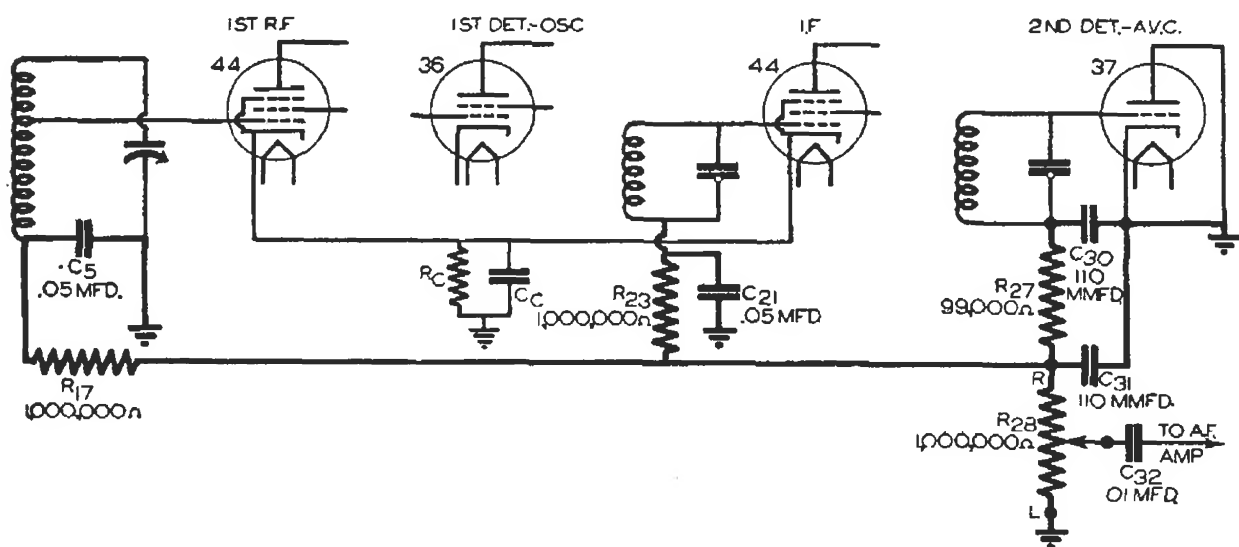


Fig. 10. Simplified diagram showing (in heavy lines) the A.V.C. system of the Philco Model 71 superheterodyne broadcast receiver. The values of the parts are the same as those used by the manufacturer.

cillator signal to give a modulated I.F. signal; 3, the I.F. amplifier.

It is common practice to apply the A.V.C. voltage to all preselector stages, in order to prevent overloading of the mixer-first detector. In those cases where a variable mu or super-control R.F. pentode tube is used for the mixer-first detector, this stage is sometimes A.V.C.-controlled. The first I.F. amplifier stage following the mixer-first detector is invariably A.V.C.-con-

few typical A.V.C. systems as used in actual receivers. Since we are interested only in the A.V.C. circuit and the A.V.C.-controlled stages, we will simplify the circuit diagrams by showing only these circuits.

A.V.C.-controlled tubes should always be variable mu screen grid tubes or super-control pentodes, for these tubes give essentially linear amplification over a wide range of C bias voltage values. If ordinary triode, screen

grid and pentode tubes were A. V. C.-controlled, changes in C bias voltage would cause the R.F. signal to swing beyond the linear region of the tube characteristic, or even beyond the plate current cut-off point, with distortion resulting.

Early Diode Detector-A.V.C. Circuits. One of the first receivers to use a diode tube as a combination demodulator and source of A.V.C. voltage was the Philco Model 71, the circuit diagram of which is shown in simplified form in Fig. 10. Since diode tubes were not available at the time this receiver

The D.C. voltage developed across R_{28} for A.V.C. purposes is filtered for the first I.F. amplifier tube by R_{23} and C_{21} , and is filtered by R_{17} and C_5 for the first R.F. amplifier tube. The time constant of each filter is about .05 second. Notice that both the R.F. and I.F. amplifiers get their minimum C bias voltage from the combination of R_C and C_C in the common cathode lead of the first R.F. tube and the I.F. tube. In this receiver the mixer-first detector has no A.V.C. control. (The 38 tube also acts as an oscillator, so A.V.C. is undesirable on this stage.)

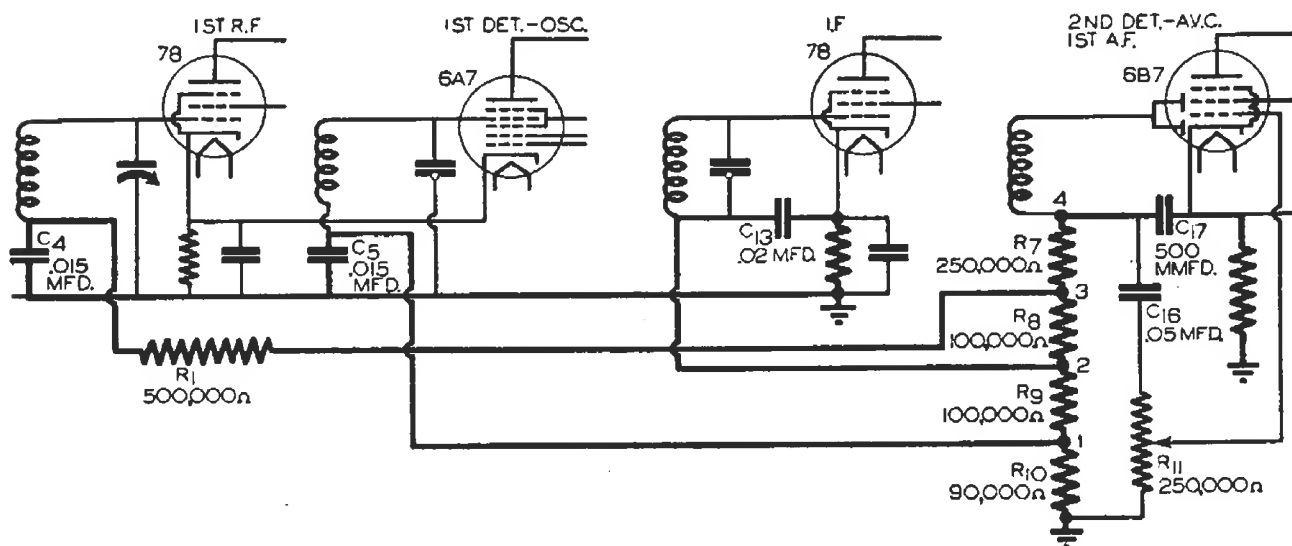


Fig. 11. Simplified diagram showing the A.V.C. system of the Arvin Model 25 superheterodyne auto radio. Notations on the parts are the same as those used by the manufacturer.

was manufactured, the grid and cathode elements of a triode were used, with the plate connected to the cathode as shown in Fig. 10. The diode load, across which exists the A.C. and D.C. components of the rectified detector output, is here made up of two resistors in series, R_{27} and R_{28} , with A.V.C. voltage being taken from the mid-point of the two resistors. R_{28} is a 1-megohm potentiometer with the movable tap connected through a D.C. blocking condenser to the input of the A.F. amplifier, thus providing manual volume control. R.F. currents are kept out of the A.V.C. system and the A.F. amplifier by the filter C_{30} , R_{27} and C_{31} .

Staggered A.V.C. Circuit. An example of a superheterodyne receiver circuit in which less A.V.C. voltage is applied to the amplifier stages near the second detector than to the first R.F. stages is the Arvin Model 25 auto radio circuit, shown in simplified form in Fig. 11. The chief disadvantage of a diode detector, its lack of amplification, is here offset by the use of a type 6B7 duo-diode-pentode tube, with the two diode plates connected together to serve as a single diode detector and the pentode section connected to serve as the first A.F. amplifier stage. This three-in-one tube was created along with the duo-diode-triode to meet the

demands of receiver manufacturers who recognized the many advantages of a diode detector in A.V.C.-controlled receivers.

The diode detector load in Fig. 11 is made up of four resistors, R_7 , R_8 , R_9 and R_{10} , connected in series between point 4 and ground. Condenser C_{17} provides a path to cathode for R.F. sig-

The mixer-first detector tube gets the lowest A.V.C. voltage, from point 1, while the I.F. amplifier tube gets a greater A.V.C. voltage from point 2. There are no filter resistors in the A.V.C. leads for these last two stages, fast A.V.C. action being desired in preference to complete protection from A.F. signal feed-back.

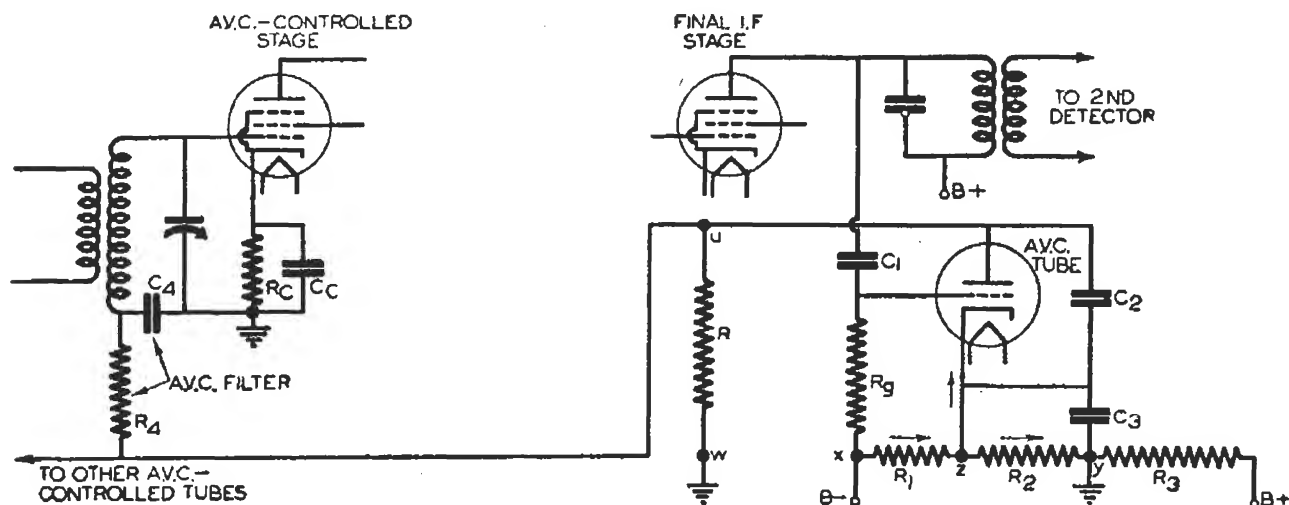


Fig. 12. Basic circuit for an A.V.C. system in which a separate triode tube is used to provide the A.V.C. voltage.

nals in the detector circuit. The A.C. and D.C. components of the detector output voltage appear across the resistor combination, with points 1, 2, 3 and 4 increasingly more negative with respect to the chassis or ground; when several different values of A.V.C. voltage are provided in this way, the voltages are said to be *staggered*. The A.F. voltage is fed to the control grid of the pentode section from the movable contact of potentiometer R_{11} which, with D.C. blocking condenser C_{16} , is connected across the diode load resistors.

As you can see, the grid of the first R.F. tube is connected to point 3, where it gets the highest A.V.C. voltage of any tube. The filter network for this tube, made up of C_4 and R_1 , has a time constant of .0075 second. This is the only tube in the receiver which has time delay, for fast A.V.C. action is desirable in an auto radio to compensate for changes in signal level when driving.

Circuits with Separate A.V.C. Tubes. Before the diode detector came into widespread use, a triode tube in a separate A.V.C. stage was commonly used to provide the required A.V.C. voltage. One basic circuit for this is shown in Fig. 12.

Let us consider the circuit first for the condition where no R.F. signals are being fed to the grid of the A.V.C. tube. Resistors R_1 , R_2 and R_3 form a voltage divider network which is connected across the power pack output terminals, hence electron flow is from B— to B+ through these resistors. This makes point x negative with respect to point z , and the grid of the A.V.C. tube (connected to x through grid resistor R_g) is therefore *negative* with respect to its cathode.

How does the A.V.C. tube secure its plate voltage? Trace from point z through the cathode-plate path of the A.V.C. tube to point u , through A.V.C. load resistor R to point w and the chas-

sis, then through the chassis to grounded point y on the voltage divider; this shows that the tube and R are in series across voltage divider section R_2 , with each getting a portion of the voltage across R_2 . The values of R_1 and R_2 are so chosen by the designer that the A.V.C. tube is biased to cut-off when there is no R.F. signal. Under this condition no current flows through R , making the plate of the A.V.C. tube positive with respect to its cathode by

the peaks of the pulses varying according to the modulation signal. The R.F. component of this plate current is filtered out by C_2 and C_3 , while the D.C. and A.F. components appear across R . Electron flow is from u to w through R , hence point u is negative with respect to ground. A.V.C. filters in each controlled stage filter out the A.F. component, while the D.C. component, which varies with R.F. carrier level, is fed from point u to the grids of the con-

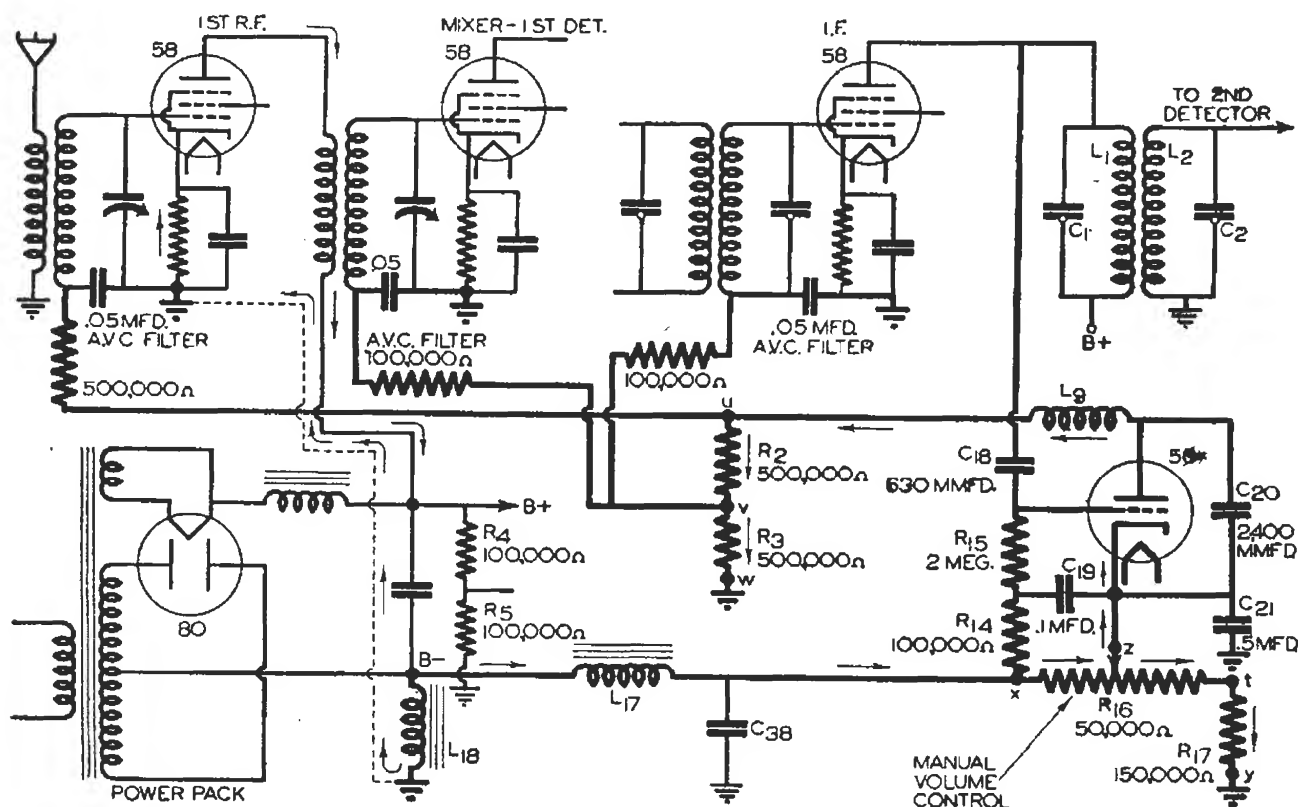


Fig. 13. Simplified diagram showing the A.V.C. system of the RCA Model R-74 superheterodyne receiver. This set uses a separate triode A.V.C. tube for producing the A.V.C. voltage. The arrows indicate the directions of electron flow for D.C. Notations on the parts are the same as those used by the manufacturer.

an amount equal to the voltage across R_2 . Furthermore, under this condition points u and w are at the same potential, that of the chassis or ground, and no voltage is fed to the A.V.C.-controlled stages. A cathode resistor R_c is therefore required in each controlled stage to provide normal C bias voltage.

When an R.F. signal acts on the grid of the A.V.C. tube through C_1 , it swings the grid in a positive direction on alternate half-cycles; this allows a pulsating R.F. plate current to flow, with

trolled tubes. An increase in carrier level at the grid of the A.V.C. tube increases the D.C. component of voltage across A.V.C. load resistor R just enough to make the grids of the controlled tubes sufficiently more negative to hold the carrier level essentially constant, as in normal A.V.C. action.

Example of Receiver Using Separate A.V.C. Tube. The RCA Model R-74 superheterodyne receiver is an example of a circuit using a separate A.V.C. tube. A simplified diagram of

this circuit appears in Fig. 13. First of all, notice that the R.F. amplifier tube, the mixer-first detector tube and the I.F. amplifier tube are A.V.C.-controlled. You can tell this because in each case the grid return lead from the grid coil does not go directly to ground or cathode but to points u and v , which are sources of A.V.C. voltage. The connection is in each case made through an A.V.C. filter consisting of a .05 mfd. condenser and either a 100,000 or 500,000 ohm resistor.

Resistors R_2 and R_3 in Fig. 13, serving as the load for the A.V.C. tube, divide the A.V.C. voltage into two values, the lower of which is fed to the mixer-first detector and the I.F. amplifier stage. Reduced A.V.C. voltage is necessary here because the mixer-first detector tube must handle a strong local oscillator signal in addition to the regular R.F. signal, and therefore cannot be driven as far negative as the amplifier tubes which get the full A.V.C. voltage.

Now let us see how the A.V.C. tube produces a negative bias voltage which increases with carrier level. We start at the B— terminal of the power pack, knowing that we should be able to trace all D.C. electron flow paths from this point to the B+ power pack terminal, and remembering that electrons flow into the minus terminal of a resistance and out of the plus terminal. One path is from B— to chassis through choke coil L_{18} , through the chassis to grounded points in the receiver stages, through a cathode bias resistor and through each tube from cathode to plate, and then back to B+ through the plate loads. This complete path through the first R.F. tube is indicated in Fig. 13, with the direction of electron flow shown by arrows and the chassis path indicated by a dotted line; the other paths between ground and the B+ terminal of the power pack,

one for each tube, are all in parallel with this one and can be traced in the same way. Another path is from B— through L_{18} to chassis and then through voltage divider resistors R_5 and R_4 directly to B+.

Now we are ready to trace electron flow through the A.V.C. tube (assume for the time being that no R.F. signals are present). Electrons flow from the B— terminal of the power pack through filter choke L_{17} , then through part of manual volume control potentiometer R_{16} to point z , where the electron flow divides. Some electrons go through the remainder of R_{16} and through resistor R_{17} to ground, from whence they take the various all-in-parallel paths through the tubes and voltage divider R_4 - R_5 to the B+ power pack terminal, while other electrons go through the A.V.C. tube.

Since electrons enter R_{16} at x and travel to z , x is more negative than z and the cathode of the A.V.C. tube. The grid of this tube, being connected to x through resistors R_{14} and R_{15} , thus gets a definite value of negative bias voltage which makes the tube pass a definite value of D.C. plate current. Electron flow is from z to cathode to plate, through R.F. choke L_9 and A.V.C. tube load resistors R_2 and R_3 to ground, and then to the B+ terminal of the power pack through the chassis and the other tubes in the usual manner. The voltage drops produced across R_2 and R_3 by this current make points u and v negative with respect to ground (point w); these negative voltages, applied to the grids of the controlled tubes through the A.V.C. filters add to the automatic C bias voltages developed across the cathode resistors of the controlled tubes. There is thus a different normal C bias value for each setting of the manual volume control.

Potentiometer R_{16} serves as a manual volume control, for moving contact

arm z closer to x reduces the negative bias on the A.V.C. tube and at the same time increases the plate voltage of the tube slightly. This increases plate current flow, increases the voltage drops across R_2 and R_3 , increases the negative C bias voltage on the controlled tubes, reduces amplification and therefore reduces volume. Moving contact arm z away from x therefore increases volume; with z at t , we have the same arrangement as in the basic circuit of Fig. 12, where the A.V.C. tube has a high enough negative bias to cut off its plate current. Under this condition, it is obvious that no A.V.C. voltage is applied to the controlled tubes, and gain is a maximum.

The plate voltage on the A.V.C. tube is fairly low, for the maximum voltage it can obtain is that which is produced across choke L_{18} by the flow of power pack output current through the D.C. resistance of the choke. As you can see, the A.V.C. tube connects across this choke through R_3 , R_2 , L_9 , the z - x section of R_{16} , and L_{17} . The voltage across L_{18} is therefore divided among all these parts and the A.V.C. tube.

When an R.F. signal enters the A.V.C. tube through C_{18} , the tube acts as a C bias detector in rectifying the signal. R.F. components are filtered out by C_{20} and L_9 , while the D.C. and A.F. components of the rectified R.F. signal appear across R_2 and R_3 . The A.F. component is filtered out in the usual manner by the A.V.C. filters. The D.C. component, proportional to carrier level, increases the normal D.C. voltages across R_2 and R_3 and thereby increases the bias voltages applied to the controlled tubes. An increase in R.F. carrier input to the A.V.C. tube produces an increased negative bias for the controlled tubes, reducing amplification just enough to keep the carrier input to the second detector essentially constant.

How A.V.C. Affects Receiver Selectivity. Undoubtedly you noticed in Fig. 13 that the R.F. input for the A.V.C. tube is taken from a point which is two tuned circuits (L_1 - C_1 and L_2 - C_2) ahead of the second detector. There is a definite reason for taking the R.F. input voltage for the A.V.C. tube ahead of these highly selective tuned circuits.

In ordinary A.V.C. circuits like those in Figs. 9, 10 and 11, where a diode tube serves both for A.V.C. purposes and for demodulation, we know that when all of the receiver tuning circuits are adjusted exactly to resonance the A.V.C. circuit will vary the gain of the R. F. amplifiers in accordance with the level of the desired carrier. But when the receiver is tuned slightly off the desired carrier frequency, as occurs when a station is tuned in, the carrier level at the A.V.C. input point is greatly reduced by the selectivity of the tuning circuits, and the A.V.C. circuit naturally increases the amplification to offset this. The broadcast thus comes in with about the same volume as before, but is slightly distorted due to incorrect tuning and has a strong noise signal in the background. In the older receivers this was quite objectionable, for listeners were accustomed to tune a receiver according to loudness and this A.V.C. action prevented them from using loudness as a guide. The radio expert would tune a receiver like this for minimum noise, but the average person did not know this little trick and blamed the receiver for the distortion and the apparently poor selectivity.

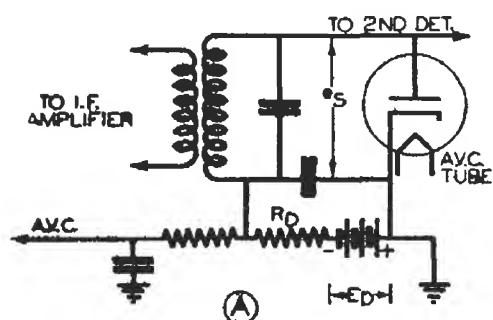
The solution to this tuning problem involved connecting the A.V.C. tube to a point farther ahead of the demodulator, where there was less selectivity and where the carrier level for the A.V.C. stage remained fairly constant as the receiver was tuned slightly off the incoming signal frequency. This kept the gain of the receiver fairly

constant, allowing the listener to tune for maximum output from the remaining I.F. stages. The R.C.A. circuit in Fig. 13 is an example of this arrangement; with their receiver, loudness could be used as a guide in tuning and good selectivity was obtained.

You will occasionally find the A.V.C. system connected considerably ahead of the second detector in modern receivers; although this practice is desirable it is not entirely necessary. Most receivers are now equipped with tuning aids to indicate when the receiver is correctly tuned.

DELAYED A.V.C.

As you already know, A.V.C. action is undesirable on weak signals, for it reduces amplification a certain amount even on these weak signals. The "trick" which receiver designers use to delay the action of A.V.C. until a definite R.F. input signal (the threshold voltage in Fig. 8) comes through is quite simple, and involves merely the insertion of a fixed D.C. voltage in series with the load resistor of the diode A.V.C. tube.



the plate negative with respect to cathode, and thus no current can flow through R_D . Any R.F. input voltage e_s (secured from the I.F. amplifier) which has a peak value less than the delay voltage E_D will not make the diode plate positive, and hence there will be no A.V.C. voltage developed on weak signals. This is indicated in Fig. 14B, where the R.F. signal peak is considerably lower than the delay voltage E_D and cannot therefore make the plate positive. In Fig. 14C the peak input signal just equals the delay voltage; plate voltage is thus zero on peaks, but still is never positive. In Fig. 14D, however, the R.F. input signal peak is greater than the delay voltage, and the difference between these two voltages (the shaded area of each pulse) is effective in sending rectified current through R_D for the production of an A.V.C. voltage.

When the positive terminal of the delay voltage source is grounded, as in Fig. 14, this delay voltage places a negative bias on the grids of the controlled tubes at all times. By careful circuit design this can be made to serve

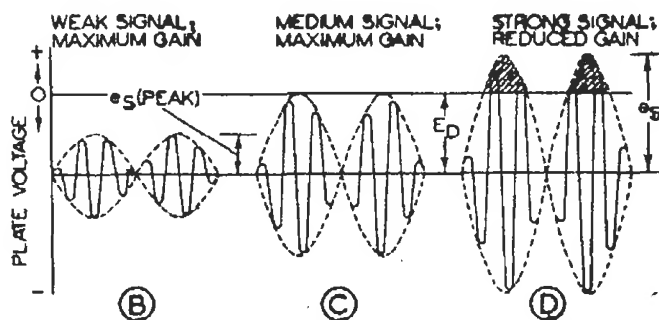


Fig. 14. Basic circuit for delayed A.V.C. action, and curves illustrating how delayed A.V.C. provides maximum amplification for weak signal. E_D represents the D.C. delay voltage, while e_s represents the peak value of the amplified R.F. signal.

The basic circuit arrangement for delayed A.V.C. is shown in Fig. 14A; a separate diode rectifier tube here is used for A.V.C. purposes. D.C. voltage E_D is placed in series with load resistor R_D with polarity as indicated. When there is no R.F. signal input, only this D.C. delay voltage is acting on the plate of the diode A.V.C. tube; it makes

as normal C bias for the controlled tubes, eliminating the need for automatic C bias. The ground could just as well be at the negative terminal of E_D , however. This would put E_D in the cathode circuit of the diode, where it would have no direct effect upon the controlled tubes, and would serve only the function of delaying A.V.C. action.

A separate diode is a necessity when delayed A.V.C. action is employed to give maximum amplification of weak signals, for with a common detector-A.V.C. tube the delay voltage would prevent demodulation of weak signals and would cause distortion on medium-strength signals through cutting off of the negative peaks of the A.F. signal.

Delayed A.V.C. Circuit Using Double-Diode Tube. An excellent practical example of delayed A.V.C. is the Silvertone receiver circuit shown in Fig. 15. Section D_1 of the double-diode 6H6G tube serves as second detector, section D_2 serves as A.V.C. tube, and the voltage drop across resistors R_{10} and R_{11} in the power pack circuit provides the delay voltage E_D . Let us analyze the detector circuit action first.

The output R.F. signal e_s from the I.F. amplifier is fed directly to diode detector D_1 through C_{15} , causing rectified current to flow from cathode to plate, through L , R_4 and R_5 to the chassis, and then through the chassis to the cathode of D_1 . The A.F. voltage developed across a part or all of R_5 is fed through C_{22} to the grid of the 6F5G first A.F. amplifier tube. Incidentally, the grid of this A.F. tube gets its negative bias voltage from the voltage drop across resistor R_{11} (one of the delay voltage resistors).

Now let us analyze the delayed A.V.C. circuit. Condensers C_{14} and C_{15} feed the R.F. signal e_s into diode section D_2 . The plate of this diode is made negative with respect to its cathode (which is grounded) by a connection through load resistor R_7 to one end of resistor combination R_{10} - R_{11} , through which the power pack output current flows to produce a delay voltage. This delay voltage also serves as minimum or normal C bias for the controlled tubes.

Weak signals undergo detection in the conventional manner in D_1 , but

cannot overcome the delay voltage which makes the plate of D_2 negative and hence no A.V.C. voltage is developed across R_7 . Strong signals are likewise detected normally by D_1 ; they also make the plate of D_2 positive on the peaks of alternate half-cycles, and electron flow is from cathode to anode of D_2 , then through A.V.C. load resistor R_7 and through resistors R_{10} and

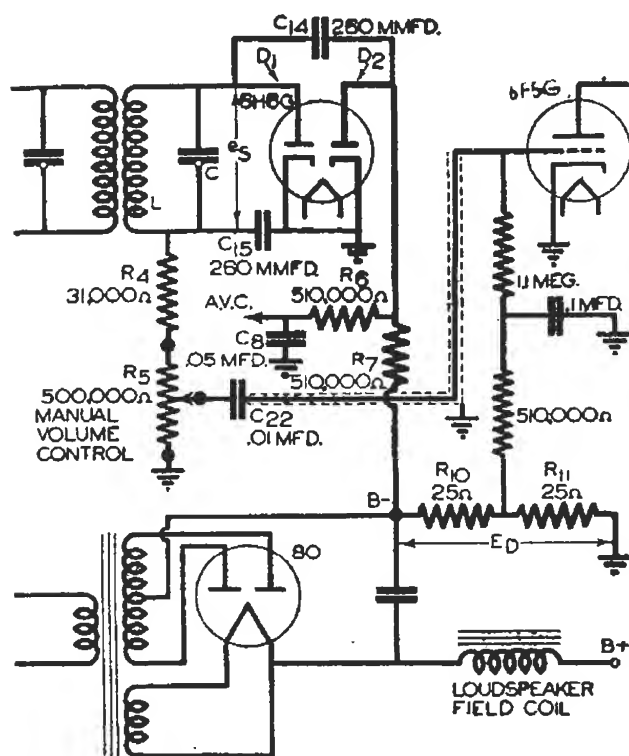


Fig. 15. Simplified diagram showing the delayed A.V.C. system of the Silvertone Model 1986-1987 superheterodyne broadcast receiver (chassis No. 100150). Section D_2 of the double-diode tube produces across resistor R_7 the desired A.V.C. voltage.

R_{11} to ground and back to the cathode of D_2 . The D.C. component of the voltage developed across R_7 is the A.V.C. voltage; it adds to the normal negative bias voltage E_D and thus amplification is reduced when strong signals come through. The A.F. component of voltage across R_7 is kept out of the controlled tubes by A.V.C. filter R_6 - C_8 .

IDENTIFYING A.V.C.-CONTROLLED TUBES

Ordinarily you will have no trouble in locating the A.V.C. tube on a sche-

matic circuit diagram, for it is now general practice to identify tubes and their functions right on these diagrams. It is not customary, however, to indicate which tubes are A.V.C.-controlled. In order to determine this, you must know the usual methods of applying the A.V.C. voltage to a tube. Three common methods are shown in Fig. 16. You will observe that in each of

also as an R.F. by-pass from the tuning coil to ground.

In the I.F. amplifier stages of superheterodyne receivers the tuning condenser is of the trimmer type and is shunted directly across the tuning coil. The circuit arrangement in this case is as shown in Fig. 16B, the A.V.C. voltage still being fed through the tuning coil.

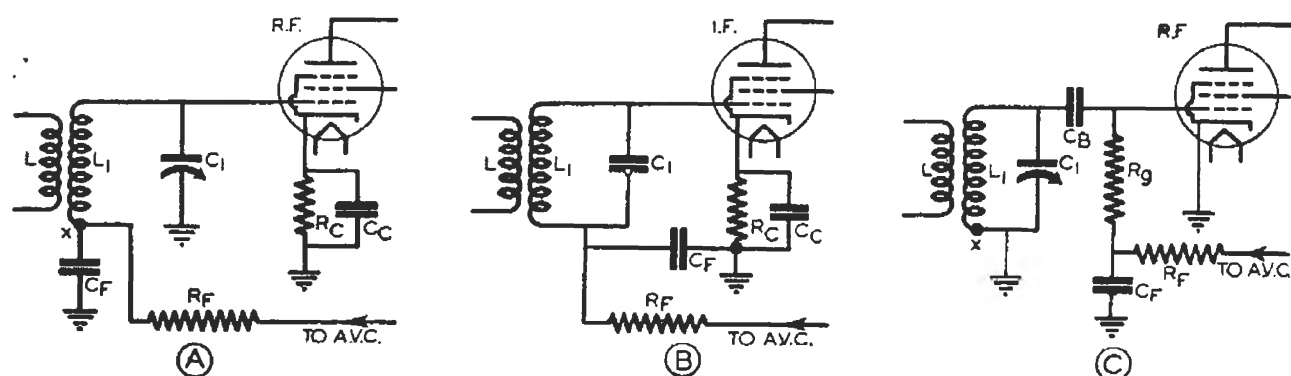


Fig. 16. Common methods of applying A.V.C. voltage to the grids of A.V.C.-controlled tubes.

these circuits the control grid does not trace directly through a conductive path to ground, chassis, B— or C—, but instead traces through an A.V.C. filter resistor to the A.V.C. tube load.

In the circuit of Fig. 16A the A.V.C. voltage is fed to the control grid through the coil (L_1) of the tuned input circuit after being filtered by R_F and C_F ; R_C and C_C together furnish the minimum negative C bias for the tube, this being applied to the grid through the chassis and the conductive path of the A.V.C. system (this path is not shown here but can be traced in any of the A.V.C. circuits already studied). With this arrangement, tuning condenser C_1 cannot be connected directly to point x on coil L_1 , because of the fact that the rotor of this condenser is nearly always grounded directly to the chassis. Condenser C_F therefore serves

Occasionally the low R.F. potential end of the tuning coil (point x in Fig. 16C) is grounded, thus giving a direct connection between this coil and the grounded rotor of the tuning condenser. In this case the A.V.C. voltage must be applied through grid resistor R_g , with blocking condenser C_B used to prevent the A.V.C. voltage from being grounded by tuning coil L_1 . Again the grid traces conductively to the A.V.C. system. To prevent loading of resonant circuit L_1-C_1 and broadening of its response characteristic, resistor R_g must have a resistance of at least 500,000 ohms. Observe that the cathode is grounded directly; this indicates that the A.V.C. system furnishes the minimum negative C bias voltage in this arrangement. There are two A.V.C. filters, R_F and C_F being the first, and R_g with C_B making up the second.

Construction Of Manual Volume Controls

Variable resistors or potentiometers which are used as manual volume controls are either of the wire-wound type or of the carbon type. Examples of each type are shown in Fig. 17; as you can see, the general appearance gives no clue toward identifying them.

The total resistance as measured with an ohmmeter between the left (*L*) and right (*R*) terminals of a volume control is a rough guide for identifying the type of construction used. Units which have resistances below 5,000 ohms are generally wire-wound; small-diameter resistance wire such as nichrome wire is wound on a thin, long and flexible rectangular strip of fibre and the strip is then curled into a semi-circle which fits into the cylindrical metal or bakelite housing of the unit. Insulating material separates the resistance unit from the housing. A movable contact arm, connected to terminal *C*, provides a means of contact to any point on the winding.



Fig. 17. Two representative manual volume control potentiometers. In each case two nuts are provided on the threaded tubular projection of the housing (through which the shaft runs) to permit clamping the control to a receiver chassis. Only a single mounting hole is needed.

Volume controls which have resistances above 10,000 ohms are ordinarily of the carbon type, although wire-wound resistances can be obtained with ohmic values up to 50,000 ohms for special purposes. It is safe to assume that all volume controls above 50,000 ohms are of the carbon type.

It is interesting to know how carbon type volume controls are made. In one

type of construction, a thin rectangular strip of insulating material is first coated with a kind of carbon paint, made by mixing highly pulverized carbon particles with water; one mixture of this nature is sold under the trade-name *Aquadag*. The strip is then curled as shown in Fig. 18A and mounted in the metal housing of the control.

The insulating strip is often cut in the shape of a round horseshoe like that shown in Fig. 18B, so the element can be mounted flat against the back of the

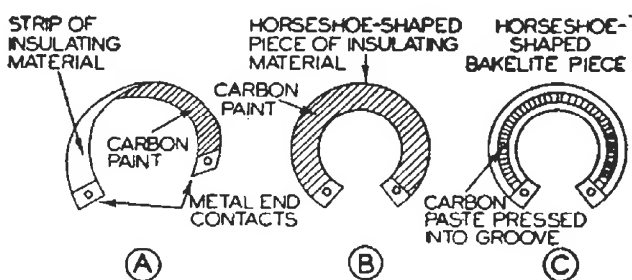


Fig. 18. Three types of construction used in carbon type volume control potentiometers.

housing without curling it. Another scheme involves the molding of a grooved circular horseshoe from bakelite, and pressing into the groove a carbon paste which serves as the resistance element; this type of construction is shown in Fig. 18C.

Each resistor manufacturer generally has his own method of applying the carbon solution or paste and treating it to give greatest dependability during use. Although sliding friction contact arms are used on wire-wound resistors, some form of roller contact which applies direct pressure to the resistance element is generally used with carbon type controls. This is necessary because the carbon elements do not stand up well under constant friction.

Wire-wound volume controls can be made with less than 5% variation in their resistance values (making the resistance of a 1,000 ohm unit anywhere between 950 ohms and 1,050 ohms;

engineers call this a *5% tolerance*). Carbon resistors cannot ordinarily be made to such close tolerances; a tolerance of 20% appears to be customary with ordinary controls.

Exact values of resistance for volume controls are fortunately not required in ordinary circuits; only where

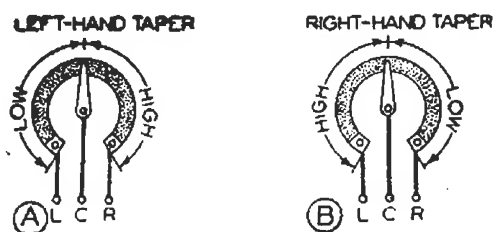


Fig. 19. Different resistances between the two halves of a volume control indicate a tapered control.

the volume control is a part of a power voltage-dividing system is it necessary to observe a close tolerance. Variations of from 20% to 40% in the total resistance of a volume control are perfectly satisfactory in ordinary receiver circuits. This is important for you to remember, as you can replace a defective 100,000 ohm volume control with either a 75,000-ohm or 140,000-ohm unit and still secure satisfactory results.

TAPER

The manner in which the resistance of a volume control is distributed is of vital importance, even though the exact resistance of the unit can vary over wide ranges; this distribution of resistance is called the *taper* of the unit. If the resistance is uniformly distributed, so that varying the movable contact a definite amount causes a uniform change in resistance between points *R* and *C*, we say that the volume control has a *linear taper* and is therefore a *linear control*. Thus a linear control set at $\frac{1}{4}$ of its total rotation would give $\frac{1}{4}$ of the total resistance; similarly, at $\frac{1}{2}$ of the total rotation there would be $\frac{1}{2}$ of the total resistance.

Volume controls are usually expected to increase the receiver output volume

when the knob is turned in a clockwise direction (making the top of the knob move from left to right). The volume control is usually mounted on the radio chassis in such a way that the shaft, on which the knob is fastened, always points toward the person adjusting the control.

The diagrams in Fig. 19 show the essential elements of a volume control as they are when the shaft points toward you. If the resistance between terminals *C* and *L* increases uniformly as the contact arm is moved away from *L* and toward *R*, we have a linear control and curve 1 in Fig. 20 will repre-

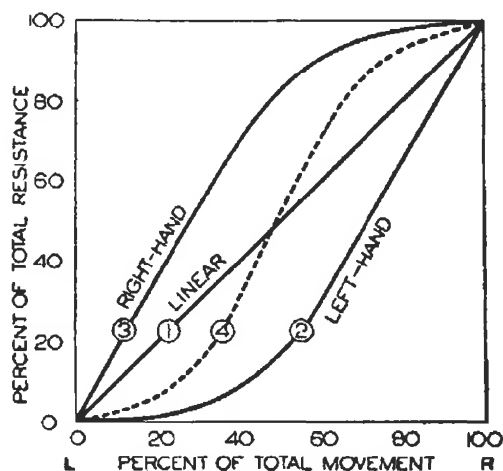


Fig. 20. Curves showing variation of resistance between terminals *L* and *C* with movement for three types of tapered volume controls and for a linear volume control.

sent its variation of resistance with control knob movement or rotation.

Left-Hand Taper. If, in moving contact arm *C* of a volume control unit from *L* to *R*, the resistance between *L* and *C* increases slowly at first and then more rapidly and uniformly after the half-way position is passed, we have what is known as a *left-hand taper* (curve 2 in Fig. 20). The taper or gradual change in resistance is here at the left-hand side of the control.

Right-Hand Taper. If the resistance between *L* and *C* in the above case increases more or less uniformly and

rapidly at first, and then increases less rapidly as the contact arm approaches terminal R , we have what is known as a *right-hand taper* (represented by curve 3 in Fig. 20). The taper or gradual change in resistance is here at the right-hand side of the control.

There is a simple way of telling whether a particular control has a right-hand or left-hand taper. With the shaft of the control pointed toward you, set the contact arm at its mid-position, as indicated in the diagrams in Fig. 19, and then measure the resistance first between terminals C and L and then between terminals C and R with an ohmmeter. If the lower resistance exists between C and L , you have a left-hand taper control, as in Fig. 19A; if the lower resistance exists between C and R , you have a right-hand taper control, as in Fig. 19B. If the resistances of the two halves are equal, you either have a linear taper or, in very rare cases, a combination right- and left-hand taper like that represented by curve 4 in Fig. 20.

Why Tapered Volume Controls Are Needed. The main purpose of a tapered manual volume control is to give changes in volume which sound uniform to the human ear for equal changes in volume control position. This means that the receiver designer must take into account the peculiar characteristics of the human ear, which prevent it from detecting changes of less than 3 db in the level of a complex sound. As examples, here are two circuits which use tapered volume controls.

A conventional diode detector circuit in which is incorporated A.V.C. and a manual volume control V.C. is shown in Fig. 21A. A study of this circuit will show you that as the movable contact on the volume control is moved from the cathode end to the diode plate end, the A.F. voltage fed to the triode

section of the tube increases. Hence, increased volume is secured when the contact arm is moved towards point R . If a conventional volume control unit is used, it should be so connected that terminal L on it connects to the cathode and terminal R to the tuned input circuit as indicated. This is done to make clockwise movement of the control knob give increased volume.

Supposing that a linear volume control were used for the circuit in Fig. 21A, let us see how it would act. We know that when movable contact C is at R the maximum available A.F. voltage will be applied to the grid of the triode section and full output volume will be obtained; likewise there will be zero A.F. voltage on the grid when C

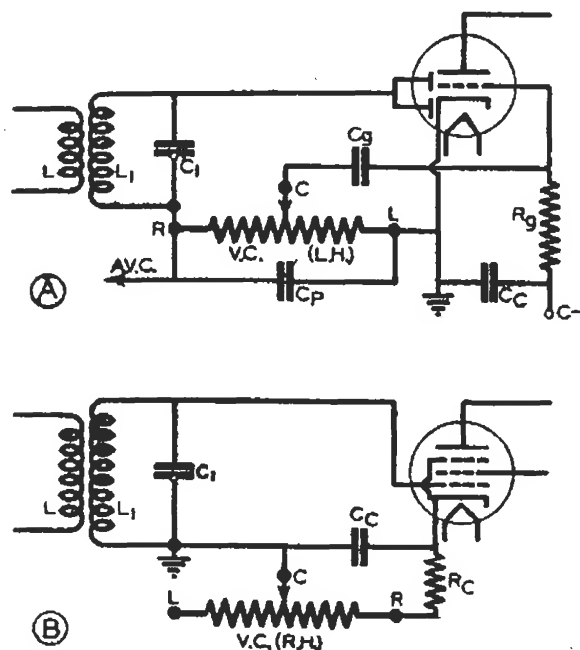


Fig. 21. Two examples of circuits which require tapered manual volume controls.

is at L , and volume will be zero. It is a known fact that a reduction of one-half in A.F. voltage corresponds to a 6 db change in sound level. Since the average human ear can just barely detect a 3 db change in the level of a complex sound, the 6 db change would be equivalent to two noticeable changes in sound.

With these facts in mind, let us reduce the volume from maximum to

zero by rotating contact arm *C* gradually from *R* to *L*. We listen carefully as we turn; at first we can detect no change in volume—our ear catches one change or reduction—we keep on turning until we can detect another reduction—now we check the volume control knob and find it is at the half-way position, so that half of the maximum A.F. voltage is being used.

We cut the voltage in half again by moving *C* from the $\frac{1}{2}$ to the $\frac{1}{4}$ position, and again get two noticeable changes in volume or a 6 db change in sound level. Moving *C* from the $\frac{1}{4}$ to the $\frac{1}{8}$ position again cuts the voltage in half, with two more detectable changes in sound. Thus as we move *C* from *R* to *L*, we get two noticeable changes in volume while moving the control knob first $\frac{1}{2}$, then $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, etc. of its total movement. Clearly a linear control gives extremely non-uniform changes in volume in this circuit, with the changes in volume being most apparent as the contact arm approaches *L*.

To overcome this non-uniform change in volume with control setting, the radio engineer uses a volume control which reduces the voltage rapidly as *C* is first moved away from *R*, then produces less change in voltage with change in setting, or allows the voltage to taper off slowly. This type of volume control would have a left-hand taper. *As a general rule, when the current through the entire volume control resistance is constant regardless of the setting of the movable contact, the left-hand taper is required.*

Another widely used manual volume control circuit is shown in Fig. 21B. Here resistor R_C sets the minimum *C* bias for the tube; increasing the resistance of manual volume control resistor *V.C.* increases this *C* bias and hence reduces the amplification and receiver volume. To make the volume increase

with clockwise rotation of the control, the right-hand terminal of the volume control must be connected to resistor R_C as indicated.

Maximum volume is, of course, obtained when contact arm *C* is at *R*. As *C* is moved away from *R*, the increase in *C* bias voltage is at first quite rapid, but increases less and less rapidly after that because advancing this volume control reduces the plate current of the tube. It therefore takes larger and larger series resistances in the cathode lead to get appreciable increases in *C* bias; what we need is a resistor which changes its resistance slowly at first, and then more rapidly. A right-hand tapered resistance, represented by curve 3 in Fig. 20, does this and is therefore used in a circuit like this.

In general, when the current through the volume control resistance changes in value when the movable contact is adjusted, a right-hand tapered volume control is used. In the *C*-bias type of manual volume control such as this, the gain of the tube does not change uniformly with changes in *C* bias. To compensate for this deviation, special tapers are oftentimes used for the volume control. An ordinary right-hand taper control will generally suffice as a replacement in these cases, however.

You have undoubtedly noticed that the terminals of the manual volume controls in the circuits of Figs. 2, 3, 4, 5, 6 and 7 are marked *L*, *C* and *R*; these markings indicate how the volume control should be connected so as to get increased volume when the control knob is turned in the conventional clockwise direction. In addition, the ohmic values of the controls are given, and each volume control is marked either *L.H.* to indicate left-hand taper or *R.H.* to indicate right-hand taper. This extra information will be of practical help to any one who is called upon to service volume control circuits.

Lesson Questions

Be sure to number your Answer Sheet 19FR-2.

Place your Student Number on every Answer Sheet.

Send in your set of Answers for this lesson immediately after you finish them, as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.

1. Do receivers which employ automatic volume control also have manual volume controls?
2. Give three reasons why automatic volume control is desirable in a radio receiver.
3. Name three types of manual volume controls which are found in radio receivers.
4. What is the most effective way of varying the mutual conductance of a tube in order to control volume?
5. What is meant by the threshold voltage in a receiver having delayed A.V.C.?
6. What signal voltage (developed by the A.V.C. tube in a radio receiver) is kept out of the A.V.C.-controlled stages by A.V.C. filters?
7. What determines the time constant of the A.V.C. filter system?
8. What three sections of a superheterodyne receiver are usually A.V.C.-controlled?
9. Which type of taper (left-hand or right-hand) does a volume control unit have if, in moving contact arm C from L to R, the resistance between L and C increases slowly at first and then more rapidly after the half-way position is passed?
10. What is the general rule for using a volume control unit which has a right-hand taper?